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# Gas Burners
for Forges, Furnaces
& Kilns

written by
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The instructions in this book are not intended to conflict with federal, state, or local ordinances and regulations of any agency having jurisdiction. You should learn and observe them at all times. You should also learn and observe the guidelines established under the Occupational Standards and Health Act. No liability is assumed with respect to the use of the information herein.

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Dedication

This book is about the future of the arts and crafts. So, it is dedicated to the innovative tool makers and multimedia artists still to come.

Introduction

With the information contained in this book you can now construct a portable forge with its own burner, for about one hundred dollars, capable of bringing heavy bar stock to welding heat in less than ten minutes from a cold start. You can also build another burner no larger than your hand that can braze, and a third burner the size of your hammer powerful enough to run iron-smelting furnaces. These burners do not use added oxygen or fan motors. Only hand tools are necessary for the fabrication of the burners and the forges, furnaces, and kilns.

Construction plans for the forges, furnaces, and burners in this book are laid out in step by step detail with drawings explaining the steps of construction. There are also alternate choices to make your work as convenient as possible. Drawings, photographs, and a list of sources are also provided.

The burners are designed for construction from readily available plumbing parts with the most exotic component being a contact tip that can be purchased at any welding supply store. The forge bodies are made from containers, and they're insulated with materials available from pottery suppliers or by mail order.

Publisher's Note

This book is loaded with information and can be overwhelming if it is taken in one reading. So focus on what is your major interest and begin there. Since I am a blacksmith, I was interested in making a forge. I started with the 1/2-inch burner and found out that it really works well. It also got me over the hangup of using and working with propane. Then I built the 3/4-inch burner and had a blast when I installed in the propane bottle forge. This is now in my garage on a purchased cart. What a relief to find that I can fire up and shut down quickly and not make a smelly mess, much to the delight of my wife and neighbors.

I also found out that it was easier to find information when I put Post-it strips at the chapter heads and at special places to return to for critical instruction or parts lists.

The Furnace Town Blacksmithing Guild, that I am a member of, is located at the site of an early American, 1827 to 1850, iron furnace. Our next major project will be developing a foundry at this site for demonstrations. We will be using the foundry furnace that Mike has designed and described in this book.

1

Safety

There is no need to feel uneasy about using gas forges if proper safety precautions are taken. You already possess the most important piece of safety equipment—your mind. Safety begins by informing yourself about every pertinent aspect of an endeavor and then using the information acquired by others to avoid learning your own lessons the hard way. Safety is established when you build a complete and accurate mental picture of what procedures are prudent, and it grows as you deliberately follow those procedures at all times until they become habit. Safety, however, ends when you decide to depart from approved practice, usually for convenience sake.

To start, learn about propane, the tools, and materials used to build a burner for a forge, furnace, or kiln and follow the manufacturer's recommendations. If you are not sure how to properly use propane or a tool, stop—ask someone who knows.

Propane safety

All of the burners described in this book are designed to run on propane gas and only propane gas, so carefully read Chapter 2, "How the Burner Works."

Always use proper ventilation when running burners. Until you learn how to properly tune a burner, there is a danger from carbon monoxide. Even a properly tuned burner will be consuming oxygen and expending carbon dioxide. There are excellent and inexpensive gas detectors available; to ensure the safety of your workspace see Gas Detectors the Resources.

If you live in an area with hard winters and must work the forge inside during bad weather, set up an exhaust hood and open the shop door or window slightly. The forge puts out plenty of heat to overcome any draft this might cause. When running a forge indoors, your local safety codes may even require that you use a specific kind of venting system—you will need to familiarize yourself with those codes.

After assembling gas equipment, check it for leaks beginning with the valve on the fuel tank, then the fittings, regulator, hoses, and burner valves using soapy water while the system is pressurized. Anytime you smell gas, check everything again and fix any leaks immediately.[1]

When starting one of these burners, it is usually necessary to partially close the choke until the burner nozzle warms up. Also, it is most important to make sure the choke is not completely closed or the burner will create a large yellow flame with a very large heat zone, endangering you and your work area.

These are naturally aspirated burners designed to generate the most heat possible. In doing so, they use more air than previous designs. If these burners are positioned facing straight down without sealing the forge penetration, spent gasses will rise past the air intake on the burner. This will seriously interfere with the burner's ability to draw in the needed fresh air to function.

When using these burners for brazing, keep them positioned at less than a vertical angle. If you see the burner flame start to hesitate or hear the burner "huff," simply decrease the angle you're holding.

To use fuel cylinders, open their valves completely. Most modern tanks have double seat valves that are meant to seal completely in both the fully open and fully closed positions. When a valve is partially open only the valve's packing seals it. A habit that older workers have of only opening the fuel valve a one-quarter turn stems from the days before flashback arrestors were installed on oxy/fuel systems. It was necessary then to be able to instantly close the valve if a workman heard the sound of oxygen burning its way back along the fuel hose toward the acetylene tank; however, it is inappropriate today.

There is much confusion between air/fuel burners and oxy/fuel systems. With an oxygen fed torch there is a possibility of flashback. This happens when oxygen infiltrates the fuel hose through a torch. In an air/fuel system there is no pressurized oxygen source, and the danger of flashback does not apply. No flashback arrestors are needed.

Use approved propane tanks only. Your dealer might fill them illegally for you, but that will not make them safe. Also, place propane tanks in positions for which they were designed. These tanks have internal safety devices, which are defeated if they are used out of position. Every propane cylinder comes equipped with a built-in spring-loaded pressure relief valve. If internal pressure increases within the tank to dangerous levels, which can easily happen on a hot day, the relief valve is momentarily forced open. This results in a small amount of gas escaping, which allows the pressure to fall back within safe limits. If the cylinder is sitting on its side, this valve is likely to be positioned below the level of the liquid, instead of in the vapor area above it. Should the valve open in this position, liquid propane will escape instead of vapor. The liquid will then immediately expand to about 270 times its pressurized volume, multiplying the risk of ignition!

Proper safety procedure requires keeping the propane tank in a well-ventilated and protected area completely separated from hot work. Use black wall pipe to run the gas from the external tank into the work areas where the gas is likely to be used. Do not use or store even a small cylinder in a building, garage or enclosed area, rather leave the tank outside running an approved hose to the work until you can build piping. Put the cap over the valve outlet when not in use to protect its parts from dirt.

"T" fittings with valves and gas rated connectors allow fuel hose to be run a short distance from piping to the work sites. The connector will not allow gas to flow when nothing is coupled to it, so it becomes an additional safety device if the cylinder valve is left open by mistake. A ball valve allows the connection to be serviced without draining the piping system and serves as insurance against leaks.

Take care not to let the fuel hose become a fire danger or a tripping hazard. Use hooks in the ceiling to hold the hose well out of the way. Also use gas rated quick

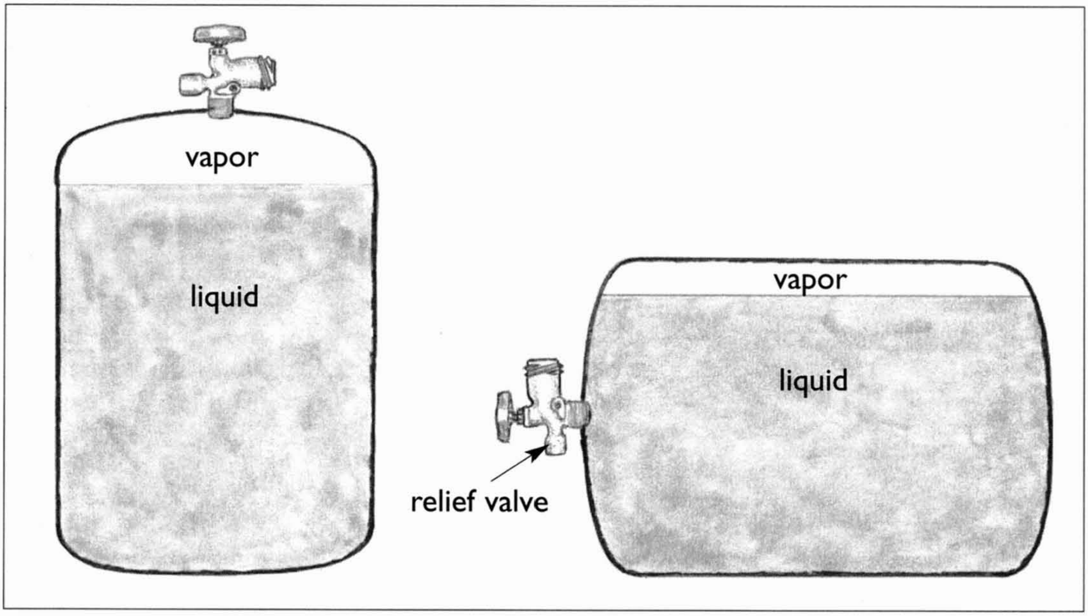


Fig. 1-1 The upright cylinder on the left shows the liquid propane lying safely below the vapor space. Only vapor will be drawn off in that position. The cylinder on its side on the right shows the main filler valve, with its built in pressure relief valve, below the level of the liquid propane. In this position liquid will be drawn off instead of vapor.

release couplings.

A portable forge and a small tank can be set up in a cart permitting the tank to be easily removed and kept at a safe distance during hot work. (See Chapter 6, "Building a Forge Cart.") The cart is also useful for transport between job sites.

Never transport or store the tank in the vehicle's passenger area or in a closed trunk. Make sure the container is secured in an upright position before transport. Do not allow the tank to be exposed to high temperatures as this could force the relief valve to open and discharge propane.

Never attempt to use a barbecue regulator or an oxygen regulator with fuel gasses. Use only regulators that are rated for the particular fuel gas you are using. A word of caution about acetylene regulators—the red zone above fifteen PSI is applicable only to acetylene, but you must make sure that the regulator will accommodate propane; better brands, but not all new acetylene regulators will, most old acetylene regulators will not accommodate propane..

Use only approved hoses, valves, and fittings. This includes the fittings for copper tubing if you decide to "plumb" your forge connections. Do not use tubing on the high-pressure side of a regulator, and use a gas-approved sealant on all pipe thread.

Procedures for safely starting, running, and shutting down the forge or furnace are given at the end of the forge-building chapter. Learn the safety codes in your area as they apply to fuel gas equipment and comply with them. They are meant for your

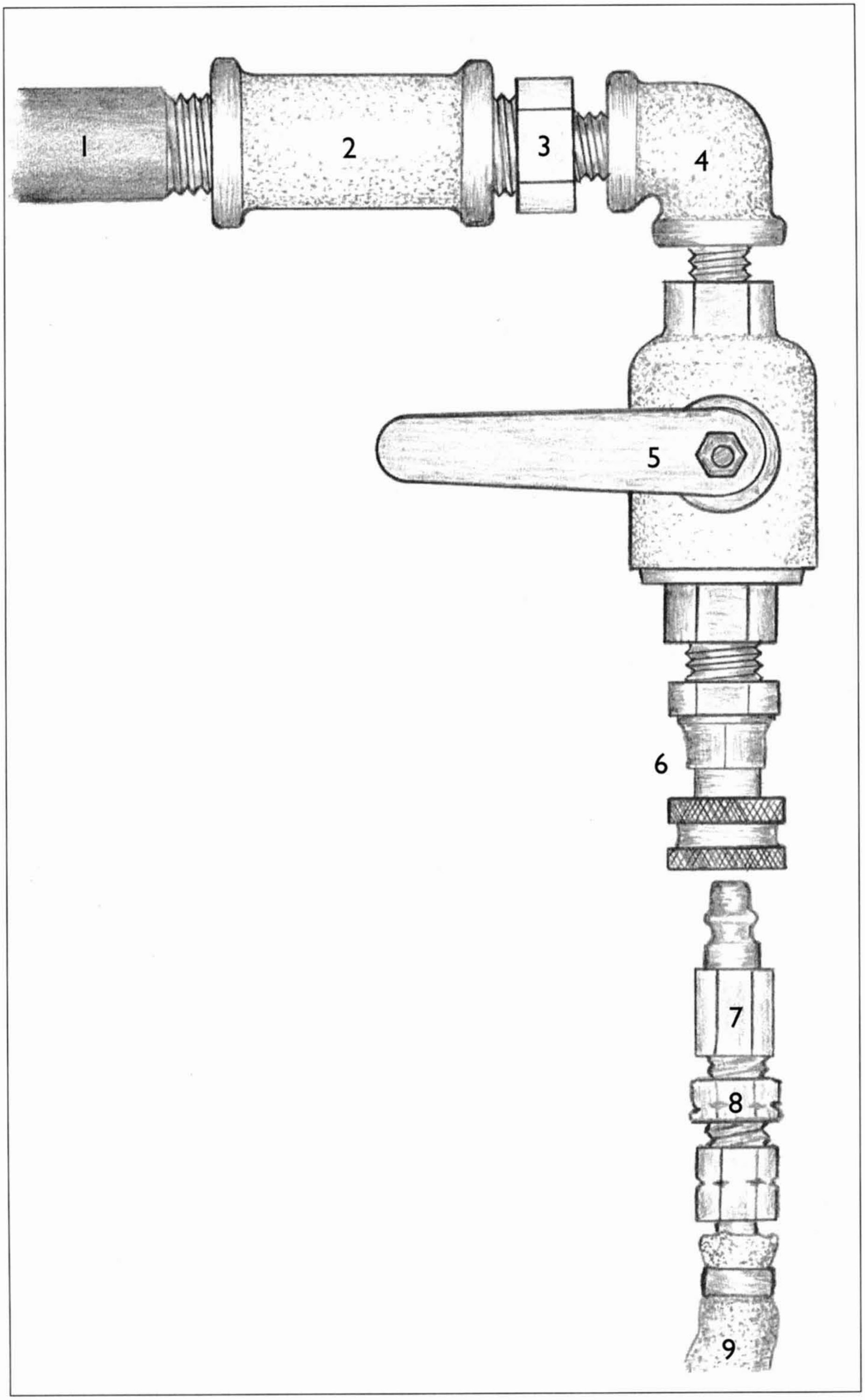


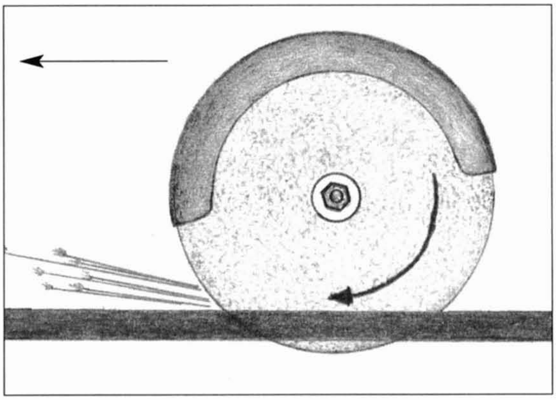
Fig. 1-2 The end of a typical hard piping run set up with the fuel hose connection on its end: (1) 1/2-inch threaded black wall pipe, (2) pipe coupling, (3) 1/4-inch to 1/2-inch bushing, (4) 1/4-inch 90 degree elbow fitting with short nipples, (5) typical 1/4-inch gas rated ball valve, (6) gas rated female quick disconnect, (7) male quick disconnect, (8) 9/16-18 LH thread to 1/4 MPT outlet bushing, (9) fuel hose with 9/16 LH fuel nut. Propane hoses also use flared fittings in some configurations. In such a case, part number eight would change to a flared fitting. The close nipples between parts #3 and #4, #4 and #5, and parts #5 and #6 are not numbered.

protection, so ask your local fire department and building inspector. Ultimately, your best safety device is awareness. Remember that building codes are laws, and when you break the law your insurance is null and void.

Tool safety

The first line of defense when you are in a work area should always be a pair of safety glasses. They should be supplemented with a face shield or welding hood when running a grinder. Rotary tools like grinders and drills have to develop a torque in order to do their work, and at times the torque can be turned against you when you forget to pay attention to the direction the grinding wheel is moving in relation to a part. The wheel should, ideally, always be brought into contact with metal so that it creates a dragging motion, resisting the direction of travel.

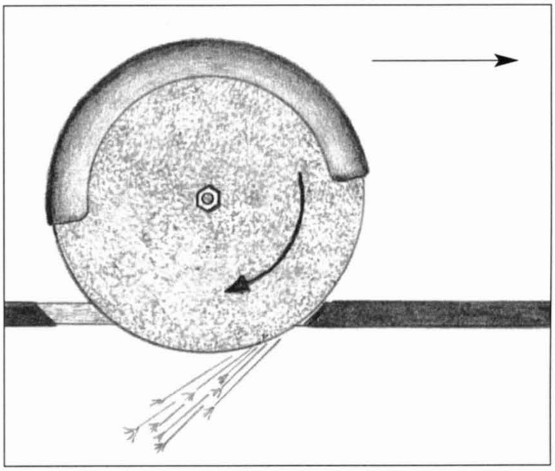
Fig. 1-3 The edge of a grinding wheel is being used to penetrate a piece of steel, creating an air opening for a burner. Note that the direction of travel here is the same as the rotation of the wheel. Friction from the blade causes the tool to "walk" the other way. It is best to move the grinder, or any rotating tool, opposite to the direction that its motion is trying to push it.



If you place the edge of the moving grinder on a test piece and move first one way and then the other, you will feel resistance in one direction. That is the safest direction to travel.

Sometimes it is necessary to travel with the grinder's pull, instead of away from

Fig. 1-4 The reversed travel direction needed as the slot is enlarged. This is because the wheel's edge can no longer touch both ends of the lengthening slot at the same time. Its tendency to pull down into the metal on one side of the wheel is no longer cancelled by the upward thrust at the other side. Friction now tends to make the wheel walk up out of the slot, but this is better than risking the wheel being pulled down into the other end of the slot, where the blade will jam. This is also the reason you are advised (in Chapter 3) not to grind to close to the ends of the air openings, but to finish forming them with a file.



it. This is when caution should be heightened. The wheel will tend to jam against the part at some point, the grinder's torque fighting the hands holding it, causing it to jump out of your grip. The 4 1/2-inch angle grinder is not likely to "kick back" hard enough to cause serious injury, but it can ruin your work piece if you hold the grinder loosely. To avoid this hazard keep the grinder in a firm grip. In case of kickback you will not have time to react, so keep enough muscle tension in your hands and arms to handle the problem before it happens. This also means that you need to keep your body balanced against kickback and the part secured. Keep the grinder held close with your elbows at your sides. It is a mistake for the beginner to assume that it is safer to keep the grinder at a distance. Holding the grinder near will also tire you far less quickly. Do not get over ambitious with a grinder. Make your finishing touches with a file. If you get tired, take a break.

Never use a larger grinder than is needed for the task. The amount of work done by a small high-speed angle grinder is on average around 70% of the amount that a large and slower moving grinder can produce in the hands of a professional, who is conditioned to running one of the big grinders. An average person using a smaller grinder will be outperforming what could be done with the larger grinder within minutes. But the risks of using the smaller grinder are far less serious.

Resist the temptation to remove the grinder's safety shield. It is true that without them the grinders are more convenient to use and your view is improved, but the new smaller grinders have a tightening screw that allows the shield to be held securely, while still being moved by hand to different positions as needed. You will be glad to have the shield in place if you mount a defective grinding wheel or if the grinder jams and shatters a wheel. The safety shield also reduces problems from hot sparks being flung off the wheel.

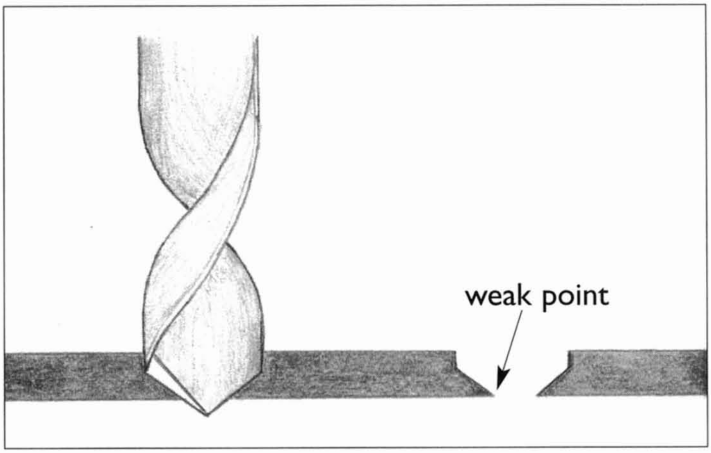
A drill motor, as with the grinder, can suddenly transfer all its torque to your arm when the leading edge of a dull bit catches in the material being drilled or when the drill bit is about to exit the far side of the material. This is a result of the pressure of the bit deforming the thinning material's cross-section. Craftsmen have an expression for this experience called a "merry-go-round." Small drill bits will usually snap off at this time. In a drill press, the part tends to be flung in unpredictable directions. To avoid the merry-go-round:

(1) Use sharp bits and lubricate with oil when drilling.
(2) Adequately secure the part in a drill press or trap it when hand drilling.
(3) Keep tension on your arms and hands when holding a drill and when grinding.
(4) Ease up the pressure when penetrating the far side of the material, since this lets you idle the bit through the thin remaining section without deforming the material. When the drill bit penetrates the material's far side the amount of pushing effort suddenly decreases. The next thing you feel, is the tug of reversed torque on the drill motor. If you are using a drill press the pressure on the quill handle will decrease and you can see the part press against its restraints.[2]

At the very least, wear a paper mask while you are handling the ceramic products and when cleaning up your work area. Using an approved respirator is even better.

Rubber gloves (dish washing type) will protect your hands and arms from the itch-

Fig. 1-5 Note the pointed edge in the steel plate that the drill bit rides on, and peels away, as it penetrates the far side of the hole. It is this edge which can tear and fold back upon itself, causing the cutting edges of the drill bit to bind against a suddenly thickened cross section of material.



ing you would experience after installing the ceramic fiber and from the mildly caustic ingredients in ceramic sealant.

In a metal shop, avoid wearing loose fitting or synthetic clothing around hot work. Opt for rugged cotton clothing and a cap. Also, when grinding or doing hot work, wear leather work boots, leather gloves and a leather apron (see Resources for protective clothing under Welding Supplies).

Never carry a butane lighter in your pocket while doing hot work.

Use UV rated dark glasses or a darkened face shield when looking into the gas forge, and wear dark glasses when using a burner as a torch.

Keep your work area swept clean, clear of oily rags, clothing, paper, paint and thinners, wood scrap, or any thing flammable. Remove dry rot in walls and paint them. Check to see that a hot piece of steel isn't going to land anywhere it can do harm.

Always keep a fire extinguisher close at hand before doing any kind of hot work. If you are working inside a building, then a charged water hose is a good back up for the fire extinguisher.

2

The Burner System and Its Fuel

In this chapter, we will explore the nature of a burner and all of its components, the fabrication of gas burners, parts for forges, furnaces, and kilns, along with the fuels used to fire these burners. There are dimensions given for the burner sizes that exist at present, along with sufficient information to allow you to design your own experimental burners and forges, but to better understand how these burners work, the fuels and related equipment are explained first.

Fuels

Gas burners described here are designed to operate only on propane gas. One may be tempted to run these burners on propylene in the open air, but if they are run inside a forge or furnace with one of the hotter fuels some precautions become necessary. Propylene will run several hundred degrees hotter than regular propane. Even propane can melt stainless steel nozzles if the burners are turned up too high in an internal environment. For hot running furnaces employ steel with a boron nitride coating for the nozzle, or use a built-in ceramic nozzle in the forge. Methane (natural gas) offers less energy than propane and is not recommended.

The burners cannot be run on acetylene or MPS. (MAPP is one of the many MPS gases.) These gasses can form explosive acetylides when coming in contact with the copper and silver used in the burner accelerator as well as the copper tubing in the forge plumbing.

These burners are not designed to use liquid fuels, pure oxygen, or hydrogen gas. Both acetylene and hydrogen are especially dangerous gasses capable of exploding when mixed with air despite the absence of a visible spark—even static electricity is enough to ignite them.

Propane fuel

Propane (C_3H_8) is a liquefied petroleum product that is used as a gaseous fuel. As a gas, technically a vapor, it is heavier than air. It tends to collect at the lowest point in crawl spaces and basements. Liquid propane becomes a gas at any temperature greater than forty-four degrees below zero unless it is pressurized. A gallon of the liquid contains about ninety-one thousand BTUs and weighs about four and a quarter pounds. Propane is colorless but has a different diffraction index than air; when ambient light is at the right level the gas can be seen as an optical distortion with wavy or shimmering lines. The pungent odor of propane comes from a chemical additive, usually Mercaptan, used to make gas leaks easier to detect.

The propane flame

Propane's primary flame temperature, when burning in pure oxygen, is rated at about 4,600°F. An air-fed propane flame is rated at about 3,600°F maximum. The average air-fed propane flame is rated between 2,000°F and 2,250°F.

Most hydrocarbon fuel gasses have similar total BTU values and similar secondary flame temperatures, but the primary flame can vary as much as 2000 degrees. Temperature ratings of fuel gases are always given as the primary flame's temperature, because that is the component that is usually relied on for accomplishing useful work. The reason propane isn't considered a very hot fuel is that so much of its potential energy is normally converted in the secondary flame.

When hot work is done out in the open, the point just beyond the primary flame is what is used to heat the work. This is because the secondary flame rapidly dissipates as it mixes with ambient air, so that its temperature quickly falls off with distance from the primary flame.

Within a forge, the secondary flame gives up much of its heat to the more controlled environment. But, it tends to become a pollution problem as it exits. The secondary flame is also less effective than the primary because it is releasing energy later in its journey along the burner tube, losing a large portion of its heat.

Still more secondary flame heat can be used in a furnace. This is because the plinth and crucible force the flame to travel a circuitous path, lengthening distance traveled before it exits. Nevertheless, a hotter primary flame is more efficient because it transfers more energy initially. The larger initial transfer, means a greater portion of its energy deposited into the thermal mass of the furnace wall overall (see "Combustion" in Glossary). It must also be noted that the secondary flame cannot effectively combust without drawing additional oxygen from ambient air. Any secondary air source is counterproductive in a forge, furnace, or most kilns. Any proper gas burner can be tuned to a neutral flame. The burners featured here can also be tuned for total primary flame combustion through a wide pressure range, transforming them into important industrial tools.

Storage cylinders

The hydrocarbon gasses, like propane, compress under very low pressure. This allows transport and storage in economical containers, which has everything to do with how inexpensive propane is. It is also the subject of most of the new safety codes.

The wall thickness on a barbecue cylinder is less than 1/16-inch, but propane is so compressible that the container can hold its pressure at temperatures up to 130°F. If that cylinder is left in full sun during a heat wave it might burst. To prevent this possibility, the containers are fitted with a hydrostatic relief valve. When the pressure rises to a dangerous level in the cylinder, the valve momentarily opens, avoiding catastrophic failure. The down side is that propane is discharged into the area around the tank. Relief valve failures are rare, but they can happen, so we have rules about where to place the tank. When you understand the mechanics of cylinder construction, none of the rules seem frivolous.

Portable propane tanks must conform to Department of Transportation (DOT) standards, and fixed place tanks to the American Standard of Mechanical Engineers (ASME). With normal wear, the DOT considers small propane cylinders that are marketed in the US to have a useable life of twelve years from their date of manufacture. Some areas of the country are adopting shorter periods of use in their safety codes. A damaged or heavily rusted tank will not qualify as safe. The tanks are required to be clearly marked with the month and year they were made. This marking is usually stamped on their protective carry-collars. Cylinders can be re-qualified according to the U.S. DOT applicable procedures after a proper inspection and the installation of an OPD valve. Your local propane dealer should be able to give you information about the availability and cost of testing. Re-certification is not cost-effective for small tanks, but with larger tanks it is worthwhile.

New tanks must be purged of air before their first filling. Containers are filled by weight or fixed liquid level gauge to prevent overfilling. A certified technician must do this.

Propane pressure within the tank increases and decreases as the ambient temperature rises and falls. DOT tanks are only filled to about eighty percent of their capacity. The remaining twenty percent of the tank volume is needed as vapor space. Over filling the container can leave to little room to allow for the liquid's expansion with ambient temperature increases, causing the pressure relief valve to open and discharge propane into the air. Or, it can cause liquid propane to enter your lines, enormously increasing the feed pressure to your forge and turning it into a flame-thrower. To prevent these possibilities an Overfilling Prevention Device, called an OPD is now required on DOT tanks from four to forty pounds.

If your tank has a triangular hand-wheel or a round wheel and has "OPD" stamped on the valve's brass body, it has the over-filling protection device. The OPD uses a float inside the fuel cylinder. This pushes a needle into an orifice as the float rises during filling. It completely closes the valve at a limit of 80% of the tank's volume. New valves also feature a back check assembly, which prevents gas flow until a proper connection is made with an inlet adapter. This blocks an accidental vapor release if the handle is opened without the tank being hooked up.

The new valves have the standard POL internal left-hand thread, but also have an additional external ACME thread for use with hand-operated connectors. This kind of connector is called a QCC (Quick Coupling Connector). The new valves still have the little bleeder valve that the service technician uses to help with proper filling, and the hydrostatic relief valve to prevent heat gain from increasing the tanks internal pressure beyond its structural limit. Laying your cylinder on its side can interfere with the proper function of the relief valve.

It is necessary for you to understand and comply with your local, State, and Federal codes when installing any kind of fuel gas system. This does not have to be a great challenge. Your local gas supplier should be able to inform you of existing rules or direct you to someone who can. Your local building department and fire department should also be helpful.

Vaporization rate

As vapor is withdrawn from the propane cylinder its internal pressure lowers. This allows more gas to boil off from the compressed liquid that causes it to cool from the "refrigeration effect." Heat lost to the expanding vapor must be replaced from the heat of the air surrounding the tank. A greater amount of propane occupies more surface area (touches more of the cylinder wall) transferring heat from a larger portion of outside air over a period of time. This is called the wetted area. Several smaller tanks hooked into a common manifold will increase the whetted area as effectively as one large tank.

Naturally, air temperature will affect this process. Together, these factors control your vaporization rate, which is the amount of gas that can be withdrawn continually without dropping the liquid's temperature below its boiling point. The larger the burner capacity, the higher the vaporization rate needed. As the liquid is used up in

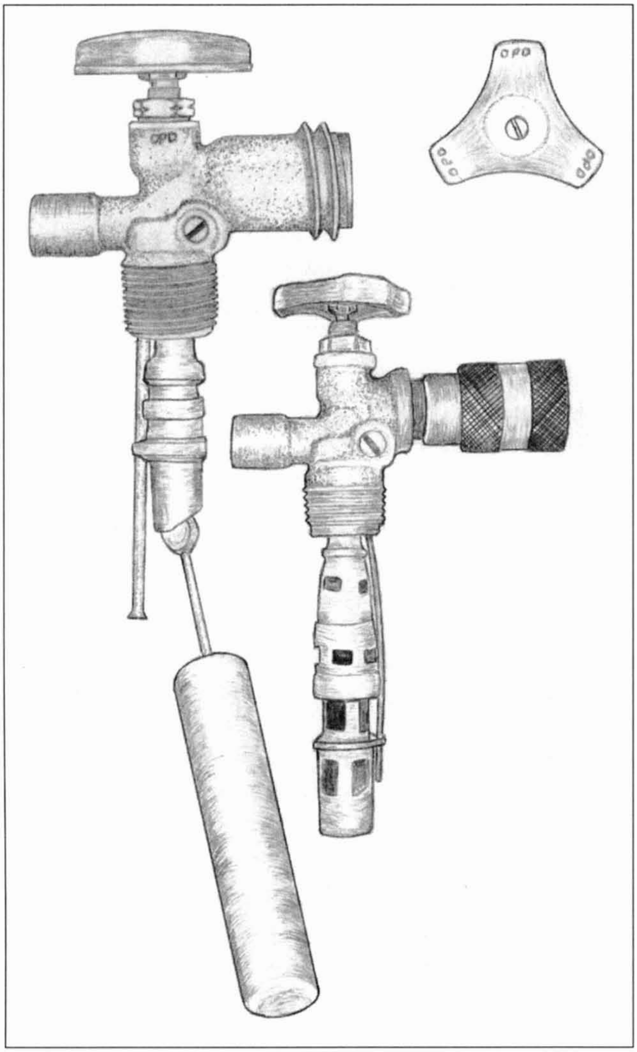


Fig. 2-1 The valve on the left is a type one which features an external Acme thread for a QCC hand coupling and an internal POL thread for older couplings. The type-two valve on the right has a spring-loaded quick-release coupling built in. It can only be used with a special male fitting. Both types automatically seal when they are not connected to their male fittings. Another difference is the two kinds of OPD cartridges that fit into their tank side openings; both cartridges work on the principle of buoyancy. The liquid fuel forces the float to close a needle valve when the proper quantity of fuel is reached, leaving a sufficient vapor space. Both valves show the pressure relief valve on the left side, the slotted screw of the bleeder valve in the lower right side of their body, and have a triangular hand wheel. The thread on the bottom openings is similar to 1-inch pipe thread, but it provides a better grip for the valve than standard NPT threading.

the tank, the wetted surface area reduces, so the vaporization rate of a large tank that is low in fuel is no better than the rate of a small tank that is full.

The maximum continuous draw of a hundred-pound cylinder, when full, would be about 300,000 BTU per hour at seventy degrees, but only about a third of that at zero degrees. A twenty-pound cylinder would start out with about one fourth of the larger cylinder's room temperature draw rate and drop to one-tenth of that at zero degrees. Temperature draw rates are especially important because the cylinders are kept outside (as required by law in most areas). What all this means to you is that you can run a 3/4-inch burner from a 20# tank on a summer day, but if you work in the cold, get at least a 100# tank.

Completely empty your cylinder before having it refilled. LPG is made up of two primary components: propane and butane. Propane boils at -43.7°F and butane at +31.1°F. When the temperature of the LPG liquid in the cylinder falls below thirty-one degrees Fahrenheit, the butane content will not boil. The propane will boil off leaving the butane behind. When you are running a large burner, or during cold weather, you will see the dew line on your cylinder turning white with frost. At this point, you are drawing off propane, only. The content that is left is growing steadily more butane rich. If you do not deliberately use up the contents of the cylinder before refilling, the enrichment problem can grow until your system shuts down in cold weather. This problem is mostly encountered with small barbecue tanks.

Fuel gauges

One of the most challenging things about gas cylinders is trying to estimate their content. Only a few barbeque 20# cylinders come equipped with a fuel gauge, but most tanks over 50-gallon capacity do. The gauge is usually located under the tank dome or cover. The numbers on the gauge show how full the tank is, expressed in percentage. They usually read from 0 to about 90 percent on the large tanks, because they are never completely filled. For the many containers without fuel gauges, marking the side of the tank with crayon is about the most practical plan. After use, dew will form on the outside of the tank's wetted area. The line at the top of the wetted area makes a usable site gauge. One company also markets a fuel level indicator strip for propane cylinders (see Resources).

Regulators

The regulator's main job is to reduce the high pressure within the tank down to a usable level before the gas enters the fuel hose and then the burner. Many regulators are preset to a very low maximum level. An adjustable regulator does this same job, but its maximum allowed pressure can be varied, making it more useful for supplying gas to tools. This is accomplished with an adjusting screw, which applies pressure against a spring. The spring rests against a diaphragm, and the diaphragm pushes a valve stem open against the resisting gas pressure in the tank. This releases gas from a high-pressure chamber into the low-pressure chamber behind the diaphragm. The gas flooding into the low-pressure chamber exerts a steadily growing counter-force on the backside of the diaphragm until a balance of forces is reached. When the screw changes position, a new balance is established at whatever pressure is desired.

Adjustable regulators come in two kinds: single and two stage. With single stage regulators, the line pressure changes as the cylinder pressure reduces, creating a need for frequent adjustment when used with high-pressure fuel tanks. Propane maintains a fairly constant pressure as it is being used; so single stage regulators are practical for use with it and are less costly.

As its name implies, a two-stage regulator has a separate high to intermediate pressure chamber with a preset limit that moderates gas pressure before it reaches the adjustable chamber. So, the pressure change within the bottle has very little affect on the adjustable pressure chamber. The practical difference between one and two stages comes from the nature of propane, because it is not a perfect gas—it is a vapor. That means it doesn't have perfectly uniform density, and this can cause fluctuation in the burner. The finer the burner is tuned, the more aggravating the problem can become. Two stage regulators are all but immune to fluctuation, where as single stage regulators are not. Two stage regulators also cost about twice the price.

There is another important difference to consider, LPG regulators were developed especially for LPG gas. They are designed to accommodate its problems and maximize its advantages. Furthermore, they have been refined over the years to do well outside where your bottle belongs, and they are designed to run well in cold and damp weather. Shop regulators weren't. A good quality propane regulator is going to give better over-all performance than a two-stage shop regulator and will outlast it if they are both exposed to the weather.[1]

The number of gauges on a regulator doesn't indicate whether it is single or two stage. Two gauges will show cylinder pressure and line pressure. A single gauge shows line pressure only. It is common to see both gauges on single stage regulators. LPG regulators don't usually have any pressure gauge at all, however, gauges can be added anywhere down-line from the regulator. If you see a plug on the regulator, it is there to seal the opening in which a gauge can be installed.

Even though a regulator is rated for your use, and even if it is tested and approved, that doesn't guarantee that it is a good choice. Choose a good quality propane regulator.

Probably, the best possible plan is to use two high quality propane regulators. Install one of them at the start of the piping system to maintain an even pressure limit. Install the other one on your forge or at the working end of the pipe in order to vary fuel pressure within that limit. The resulting system would have all the dependability of propane regulators and be even smoother than a two-stage shop regulator at about one-third of the price. Also, the second regulator can be purchased and installed at a later time.

Shut off valves

There are two kinds of valves of primary interest here: ball valves and needle valves. The ball valve is built just the way its name implies. A sphere with a hole through its center is trapped within a plastic lined cradle in the body of the valve. The sphere is attached to a stem that has a handle. When the handle is turned crosswise to the valve body, the hole is rotated sideways to the valve body's openings that closes off the gas flow. Turning the handle parallel to the body rotates the sphere's hole into alignment with the valve's openings, and the gas flow is turned on. Because the plastic liner surrounds the valve stem, completely separating it from the sphere's opening, the ball valve is the most dependable type. The hole opens directly inline with the valve's entrance and exit, thus ball valves are the least restrictive of flow. This is why the ball valve is the only type that can act as a part of the gas accelerator assembly.

Needle valves have a pointed stem, which closes against a recessed area in the valve's body in order to completely shut off flow. When partially open the flow must go around this obstruction giving a maximum of interference. The impedance is deliberate, for it allows this kind of valve to exert great impact on flow, making it excellent for fine adjustments. Where regulators control pressure—valves control flow. Of course regulators may often be used to "control flow." By providing a variable resistance (obstruction) to flow, valves can control it better than a regulator. When a single stage regulator is not sufficient to meet your tuning needs, a needle valve will help tame the problem for less cost than a two-stage regulator.

However, this type of valve is mainly sealed against gas leaks by the use of packing around its stem. It is therefore inclined to have leak problems. This weakness can best be overcome by using needle valves in conjunction with ball valves. The hand torch would be a good candidate for this plan. A needle valve would give the torch exquisite control, and a ball valve next to it would insure against leaks in the fuel system so that the torch hose can maintain a propane atmosphere when not in use.

Excess Flow Valve (EFV)

Excess flow valves restrict gas flow by closing automatically if a pipe breaks or if a hose ruptures, which assumes a complete break. The EFV offers no protection against slow leaks as from a ruptured pipe or pinhole in a hose. The valve operates in only one direction. It is has an arrow showing the proper direction for installation. The valve will automatically close if its predetermined flow rate is exceeded. Every manufacturer's catalog shows the flow rating of their valves; get the vapor rating—not the liquid rating.

When installing your own valve ask for the flow rating before purchase. These valves are being installed internally in propane cylinders in some areas in response to local safety codes. If you live in one of these areas and purchase a small propane cylinder that is normally used for powering a barbecue (appliance flows are very low), then attempt to run a forge or furnace with it, you are bound to trigger the valve. Inquire before buying and go to a larger tank if necessary.

You may need a larger line feeding the valve than would be required without it (this advice is for external valves). Never use a larger line downstream from the valve. A reduction in line size after the valve is helpful. These valves are supposed to be tested at the time they are installed and once each year thereafter. This is done by suddenly opening a shut off valve, hopefully at the extreme endpoint of the gas system. This should cause the valve to engage. Therefore, sudden opening of a valve or increasing of regulator pressure is likely to make trouble during everyday use. Excess flow protected systems require a gentle hand. This is especially true when they are used on systems equipped with fuel saver devices (see chapter 5, Advanced Design Options, pg. 82). It is recommended that the EFV be installed by a qualified technician.

Pressure gauges

When choosing a pressure gauge, remember get one that has a top limit higher than your regulator's highest output. The American National Standards Institute (ANSI) recommends an extra 25% over the regulator's output, and the gas industry has standardized gauges at double the regulator's output. The downside to these admirable notions is that you end up with a gauge that is also twice as hard to read. You are rarely, if ever, going to use the full output of even a thirty-pound regulator.

Most dial type gauges use a bourdon tube to activate the pointer. When gas passes through the "C" shaped tube, the pressure causes it to flex and elongate. One end of the tube is trapped, and the other is attached to the dial pointer, rotating it over the dial face. The parts of the gauge that the gas passes through are called the "wetted parts" and are usually made of brass. What this means to you, is that most general service pressure gauges, can be used with propane.

A low-pressure compressed gas gauge rated as commercial or equipment type is all that you need for propane. Anything more is a waste of money. Just be sure that a reliable company markets it. It is likely that your regulator will have a place to install the gauge, but if it doesn't you can mount the gauge anywhere that is convenient, as long as it is downstream from the regulator. Do not mount the gauge between the regulator and the fuel cylinder. The pressure there could easily ruin it, and you would get the tank pressure reading instead of the line pressure.

Hoses

You can run a forge using a 1/4-inch feeder line up to 25 feet. Use all 1/2-inch lines beyond that. Do not use 3/16-inch hose even for the torch whip. Your main choices in fuel hose are torch hose or standard black propane hose.

Type 85-04 high-pressure black propane hose is 1/4 inch ID and 1/2-inch OD. It is rated to 350 PSI and -45°F to +180°F, and it has high oil and abrasion resistance with good flexibility at a low temperature rating. It is a good, low cost, and tough hose although it is not as flexible as welding hose. LP gas hose comes in a variety of configurations. The two most useful kinds are the standard fuel gas fittings: (1) "B" size 9/16-18 female left-hand thread on both ends of the hose; (2) appliance type hose has a 3/8 female flare connection on one end with 3/8 male pipe thread on the other end. It is meant to be screwed directly into hard pipe and can simplify this kind of installation. If used in combination with torch hoses, a fuel thread to pipe thread connector is needed. Obtaining the kind of propane hose desired, including highly flexible hose with appliance fittings rather than left-hand fuel fittings, may require special ordering (see Resources). It can save connector problems later on.

Fuel hose is sold as single line hose in three grades: "L" for light duty, "S" for standard duty, and "H" for heavy duty. You can buy the standard twin hose, known as type "VD," which is also called a torch hose or burning lead. These hoses are available in 3/16-inch, 1/4-inch, 3/8-inch and 1/2-inch ID.

The twin hose has a red fuel line and a green oxygen line. The lines separate easily after their brass rings are filed off. The red line has "LH" (left hand) threads and the green line has "RH" threads. Fuel hose comes in three grades: tuline grade "T" is for use with all fuel gases; grade "R" is for use with acetylene only and has a non-oil-resisting rubber cover; grade "RM" is for acetylene only and has a flame and oil resisting cover over the non-oil-resisting layer. All three of these fuel hose grades are red and are rated at 200 PSI. The only way to tell the grades apart is by their marking imprinted on the hose. Make sure that the hose fittings are "B" 9/16-inch. Some twin lines are sold with size "A" fittings, which are for miniature tools and will not match any standard fittings.

There are many kinds of non-standard fuel hoses sold, some of which are armored with woven SS wire for sheathing. It is best to consider this kind for the flexible section between the outdoor cylinder and your hard piping. Rodents sometimes chew on hoses, and if extra protection is desired for the fuel hose as it nears the forge, snap-on leather hose guards are more practical than armored cable. Their use is suggested if your hose runs along the shop floor or ground.

Hose failure

Hoses break for several reasons including:

(1) Physical injury whether from one massive incident or several lesser incidents and a final mechanical stress (pulling in order to free the line from an obstruction, or catching the line in a moving part). Those injuries can come from burns or pinching the lead (as with the bad habit of twisting or pinching hoses to temporarily shut off flow when changing torches). Running over the hose with heavy equipment is a common occurrence on job sites. Closing a door on the hose can cut it—it is also common.

(2) Improper repairs to loose connections have become all too common with the spread of hose repair kits. The repair looks simple to accomplish, but proper crimping of the ferrules (this is the outer brass casing, which traps the hose securely over the hose barb) takes practice. With a loose crimp, the gas pressure will gradually start pushing the hose barb out of the hose. If this goes unnoticed an additional strain (pulling on the hose) can end in catastrophic hose failure. Too tight a crimp creates a stress point that will tear, opening a hole near the hose barb in a short period of time.

(3) Cracking from age provoked by additional stress is not as common as it once was. Partly this is because of improved materials and also the general realization that UV accelerates aging. People are becoming more aware of the need to keep hoses out of the weather when they are not in use. It is best to avoid old hoses.

(4) Low-grade hoses can pass testing procedures and be legally sold in this country. They are not recalled until after several "incidents." Common sense discourages using "barely legal" equipment when using fuel gasses or any other dangerous fluid.

Dropping heavy or sharp objects on the hose or any other mechanical stress should always be followed by a close inspection. Use your fingers to check for problems that aren't visually apparent. If there is the slightest doubt about the hose condition replace it or have it repaired. This should be done by a qualified technician on a hydraulic crimping machine, not with a hose repair kit. Situations where the hose can be burned should be avoided. Hot slag or weld berries should be kept from contacting the hose by carefully directing it out of harms way, running it overhead or by the use of a leather hose guard. The whip, a lightweight and highly flexible hose that is commonly used, must be closely inspected and replaced if not in excellent condition.

Copper tubing fittings

Both the home-built connector in the threaded fittings section and the forge's plumbing call for the use of copper refrigeration tubing and its fittings. There are two main types of copper tubing fittings: flared and compression fittings. Flared fittings are notorious for leaking, because people try to make them with cheap imported flaring tools. A flaring tool capable of making a flare that will not leak costs about $175. Have them done for you at a good hardware store or special order them from a licensed plumber.

If these options are not available, the flared end of the copper tube can be polished into a perfect match, using an abrasive and twirling it against the brass face of the mating part. Tripoli, rouge (from a jeweler's supplier), or a lapping compound from an auto supply will do the job. Be sure to thoroughly clean up all the parts with alcohol and blow the part out, leaving no trace of polishing compound.

It can be helpful to anneal the cut end of the tubing before flaring. When annealing use just enough flame and stop heating when the copper begins to turn different colors on its surface. Too much heat causes hard oxides to form on the material.

Compression fittings are more straightforward to deal with. Cut the tubing to its desired length; push the compression nut and the little brass ferrule onto it. The small ball is called a ferrule. Tighten the ferrule around the tubing until it seals both parts together; however, this fitting can work loose and begin leaking if it is subjected to physical stress. Over-tightening can cause leakage. Over-stressing the compression nut or ferrule can also ruin the fitting. Just snug the parts down and then pressure check them, tightening only as much as is needed to stop leakage.

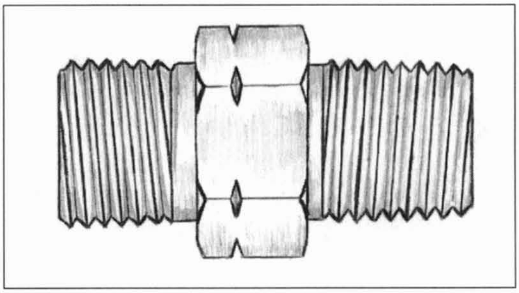
Depending on the safety codes in your area, you will probably have to use one or the other of these fittings; the choice of which kind to use will not be up to you. At the beginning of your project it may seem difficult to conform to safety codes, but knowing you're in compliance is comforting. Remember, you don't have to face every challenge presented in this book at once. If you're not comfortable installing the forge plumbing at first, put it off until you gain confidence.

Threaded fittings

The most important fitting is the one between the fuel hose and burner. It is called a connector (a coupling normally has female threaded parts). Acetylene threaded fittings (commonly used for all fuel gases) use a national coarse left-hand thread as required by code. Connectors come in various sizes. The size used with “B” fitting fuel hoses is 9/16-18 “LH.” It has left-hand thread on both of its ends with a center notched hex nut in the middle. It is used to connect fuel hoses together.

A more useful fitting is the 9/16-18 “LH” thread to 1/4 NPT outlet bushing. One end of the fitting has a standard NPT (National Pipe Thread) fitting. The other end has a left-hand fuel thread with a hex nut in the middle. The notches in this fitting are off to one side of center indicating that it is not a fuel thread on both ends. This can be a difficult part to find. The propane section of a large hardware store, propane dealers, welding supply stores, and fittings suppliers are all good candidates. You will also find this part in Resources.

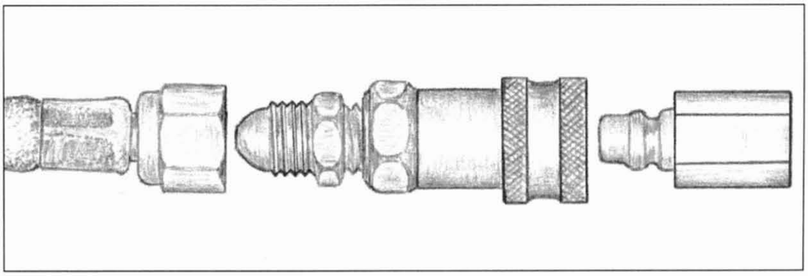
Fig. 2-2 An outlet bushing showing the left-hand thread on one side and the tapered National Pipe Thread on its right side.



Another type of connector is the gas-rated quick release fitting, Fig. 2-3. These are called quick connectors or quick disconnects. They have several advantages: quick disconnect and swivel capability. By using quick connectors you can change burners rapidly, and the supply side of the connector set closes gas tight when the male nipple isn’t connected (see Fig. 1-4). Unfortunately, they come with NPT threading on both parts, so it is necessary to buy or build a fuel thread to pipe thread connector before employing unless you use a flared nut on the fuel hose. But, with the use of multiple male nipples the one connector and fuel side (female quick disconnect fitting) you can “plug into” different burners.

You can buy “Y” valves from a welding supply store or build your own, for running the hand torch and the forge at the same time. Use gas rated valves and hose with them. If you purchase the “Y” valves, the clerk may order a simple “Y” fitting instead. The difference is that this fitting has no valves on it. You must also remember that a fuel hose “Y” valve has all left hand threads.

Fig. 2-3 The propane hose on the left has a machine attached flared nut. Next is the flared fitting screwed into a gas rated quick-disconnect. On the right is its nipple with standard female NPT thread. While a fuel fitting is needed for torch whips, flared fittings are recommended elsewhere, to prevent the wrong fuel gas from being used.



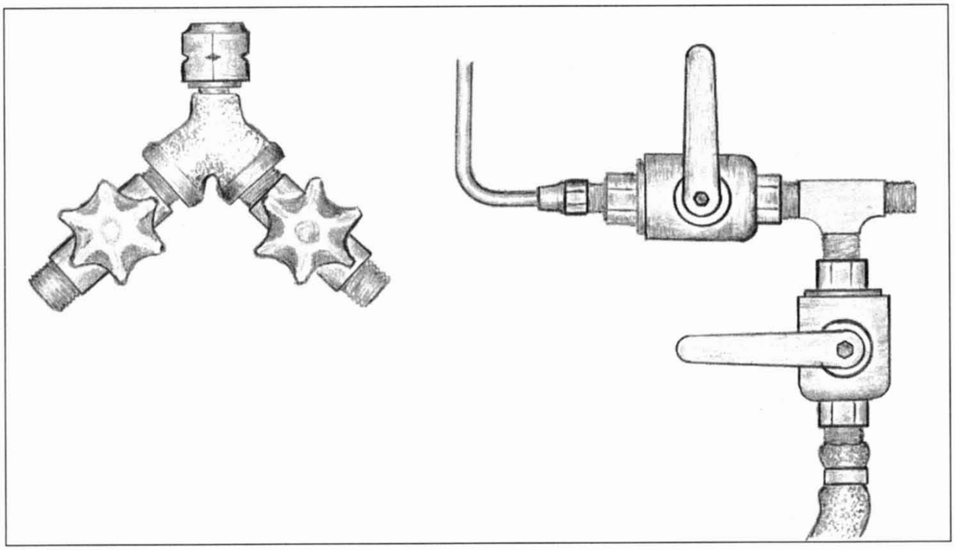


Fig. 2-4 The "Y" valve on the left comes with good quality name brand needle valves. Two ball valves and some fittings make up the fitting on the right. The small copper tube coming off its left side would travel up to a forge burner. The hose at bottom right would feed a hand torch.

Gas burners

A modern jet engine develops between 3600°F and 4000°F by compression of air and preheating of the fuel. For a naturally aspirated burner propane's maximum rated heat with an air/fuel mixture is difficult to evaluate. No scientific tests have been run on the burners that have been developed in the last three years, but it is known that they produce considerably more heat for the gas used than their predecessors, whether they are tube or compound configurations. It isn't much of a logical stretch to conclude that they are producing about all the heat that is available from mechanically manipulating a propane/air flame.

Flames are sustained chemical reactions caused by combining combustible components with oxygen with heat as the by-product. Propane is basically a combination of carbon and hydrogen atoms. When hydrogen combines with oxygen, the end product is water vapor. When carbon combines with oxygen, the end products are carbon dioxide (CO_2) and carbon monoxide (CO). Pure carbon burned in pure oxygen will produce heat and a lot of carbon dioxide, but only trace amounts of carbon monoxide. If the carbon is poorly combusted it will produce about two-thirds the heat and carbon dioxide as well as a lot of carbon monoxide.

It is obvious that too little air will produce poor combustion (a reducing flame), but it is less well understood that too much air will also create poor combustion (an oxidizing flame). Both conditions produce carbon monoxide and reduce heat. Proper combustion is a balancing act.

The venturi effect provides the motive force to obtain sufficient air. The regulator provides the pressure variance to speed up or slow down the mixture of gas and air which controls output. Different sized orifices allow the gas stream to be balanced with different tube diameters for approximate balance of the air/fuel mixture. Positioning of the movable parts (accelerator, choke, and nozzle) allows fine-tuning of the fuel air balance at different pressures. The combination of all the burner parts working together establishes flame control. The result is high heat and a clean burn. (See Glossary, Combustion)

Gas accelerator assembly

Propane consumes five times its own volume of oxygen during combustion. The amount of oxygen in air is only about twenty-two percent, so a fuel/air flame needs a lot of air provided to work properly. In a naturally aspirated burner, sufficient air is provided by causing a venturi effect. The effect is created by a jet of gas in front of an opening, such as a tube. The jet sets up a low-pressure area at the tube opening, drawing air molecules in with it. The faster the gas molecules travel the stronger the venturi effect, entraining a greater ratio of air molecules to gas molecules in the mix.

Old style burners use a crossing pipe with a small hole drilled in its side to create a gas jet in the burner's mixing chamber. The small hole in the side of a larger pipe has two built-in handicaps. The first is drag created by a pipe laid across the air path. The second problem is that every escaping gas molecule must make a turn unless it is positioned directly in front of the exit hole. That means the majority of molecules must change direction just as they are being accelerated. That change of direction during motion has to be paid for with lost momentum. Using a gas pipe in line with the air stream greatly reduces drag by placing the hole at its front, but the difference between the pipe and the orifice size means that most of the molecules still have to make a turn just at the wrong time. Gas molecules can be much more effectively accelerated if the exit hole itself becomes a tube. Just as the barrel of a rifle allows the power of the charge to accelerate a bullet by giving the expanding gas behind it time to transfer more energy to it (momentum).

MIG contact tips are used in these burners to provide a narrow acceleration tube at the end of the larger pipe. These tips have different size orifices, high quality control, and low cost. This makes them an excellent choice for use in a gas accelerator.

In restricted spaces, the area that the accelerator occupies constricts airflow. Tapered contact tips diminish this problem, and this is why they are used on the smaller tube burners. Tweco tips also have a tapered entrance to the orifice. This helps laminar flow by funneling the gas into the smaller opening.

While the contact tips for wire-feed welders are useful in creating excellent accelerators, they come in a limited number of sizes. There is a perfect orifice size for every burner tube diameter, but the contact tip may only approximate that optimum.

An orifice that is too small for the burner tube diameter will cause the gas/air mixture to run lean. Its flame will be completely oxidizing and will tend to blow out or burn back into the tube. An orifice that is too large for the burner tube size will run rich, making a reducing flame. Its heat potential will be low and it will pollute the air in your work area.

If you find that your burner's tube diameter requires an orifice size that doesn't exist or your welding store doesn't have the size you want available, then you can use torch tip cleaners to file the orifice of the next smaller size tip into the needed diameter. Don't attempt to drill the tip.

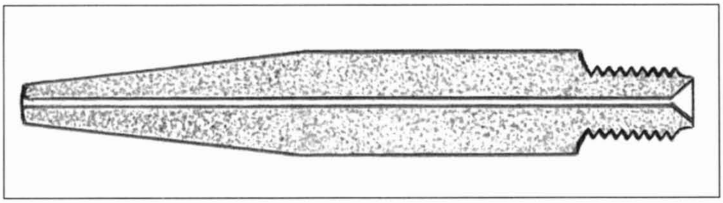


Fig. 2-5 A cross section of a typical tapered MIG welding contact tip. Note the funnel configuration of the threaded end of the orifice and its long bore. This is a nearly perfect shape for acceleration of the gas molecules.

Typically, sizes .023-inch to .063-inch are readily available. These size call-outs are for the welding wire that the contact tips are designed. Their orifice diameters run several thousandths larger.

What happens if you decide to build a tube burner smaller than 1/2-inch size? A .023-inch contact tip is already at the low end of its working range at this point. You need to find something else to take its place. Fortunately torch-welding tips come in very small sizes and can be used to answer any special need. This also holds true for large orifices.

The typical welding tip has a bend in it for convenience. Its forward section must be cut off and then threaded for use in an accelerator. Use as much of the forward

MIG Contact Tip Sizes For Burner Tube Diameters

with this book's burners

Wire Size in metric	**Wire Size** in decimal	**Actual Orifice ID** in decimal	**Burner Tube ID** standard size	**Tube Length** from front of air openings to forward cut off end
.6 mm	.023-inch	.031-inch	1/2-inch	4 1/2-inch
.6 mm .8 mm	.023-inch .030-inch	.031-inch .038-inch	3/4-inch	6 3/4-inch both tips work in this size
9 mm 1 mm	.035-inch .040-inch	.044-inch .048-inch	1-inch	9-inch filing to .046 inch gives optimum performance
1.2 mm 1.3 mm	.045-inch .052-inch	.054-inch .064-inch	1 1/4-inch	11 1/4-inch filing to .059-inch gives optimum performance
1.3 mm	.052-inch	.064-inch	1 1/2-inch	13 1/2-inch
1.5 mm	.062-inch	.070-inch	2-inch (probably)	18-inch (probably)

The chart above shows typical size relationships for the burners in this book, not of the older burners including funnel burners (where the early "Aussie" burner is retrofitted with a MIG tip accelerator), compound burners, and crude tube burners (built with rows of holes or slots for air intakes). These burners use generally smaller orifice sizes and have more choices of tip size than the older burners, illustrating the importance of aerodynamics in burner design. MIG tips also commonly come in orifice sizes all the way up to .144-inch. This would probably serve a burner nozzle about six inches in diameter. The 1 1/2-inch burner size is the largest that has been made so far (with a 2 3/4-inch ID nozzle), and very few people would use anything larger than the 1 1/4-inch burner shown in this book.

end as possible because it has an internal taper which helps gas acceleration. Remember to countersink a tapered entrance inside the threaded end to help funnel the gas into its orifice.

The next chart shows Victor welding tips. Other manufacturers have different orifice diameters for their call-out sizes, so be sure to ask for the orifice size in decimals when ordering a welding tip.

When you open the burner valve, gas starts moving all the way back to the tank. Therefore, acceleration is affected by every constriction or turn made between the fuel tank and the orifice, but the most important section for acceleration is the last few inches of the accelerator assembly. The pressurized gas is also gaining momentum in the pipe portion of the accelerator assembly. It takes between three and four inches of pipe length for the gas to reach full velocity before it encounters the contact tip. A short pipe on the accelerator will ruin burner performance (the advanced accelerator is a partial exception to the rule).

Both the position of the tip to the burner tube opening and its aim will affect burner performance. As a rule, the best performance comes from an accelerator that is axially true with the burner tube. Small diameter burners (1/2-inch or less) can be an exception to this rule. In these burners, performance can be enhanced, at some pressures, by aiming the accelerator towards the burner tube wall. This is accomplished by watching the flame as different positions are tried.

Tube burner bodies

With tube burners, the pipe or metal tube constitutes the basic body structure. The "Nine Diameters" rule states that the burner tube's length should be a minimum of nine times the inside diameter of the burner tube for proper gas and air mixing. The nozzle stick-out isn't part of the formula. The called-for diameter is the nominal or

Torch Welding Tips For Use as Gas Accelerators

Victor Welding Tip Sizes	Wire Drill Sizes	Close equivalent sizes in other drill bits	Standard pipe size in SC # 40 Burner Tube	Actual ID
Size 000	# 75	022-inch	1/4-inch	3/8-inch typical
Size 00	# 70	.028-inch	3/8-inch	[3] 7/16-inch typical
Size 0	# 65	.035-inch	1/2-inch	9/16-inch to 5/8-inch

1. These tip orifices run a little larger I. D. than what is recommended for contact tips. Torch welding tips have different gas accelerations.

2. Wire drills have close equivalent sizes in other drill bit series.

3. This .035-inch orifice will work as well as a MIG contact tip for 6mm or .023-inch wires because their actual orifice sizes are just above and below it. Also, its contouring is superior to the MIG tip.

call-out size, which is not the same as the actual ID. Half-inch water pipe for instance is actually 5/8-inch ID. You would use 1/2-inch for the formula.

Air openings

In the tube burner, lateral openings (the air intakes) are provided beside the accelerator to serve as entry ports for incoming air. Early designs used large round openings. The openings were crowded on small diameter tube bodies, so they were replaced by rows of holes, and then by slots.

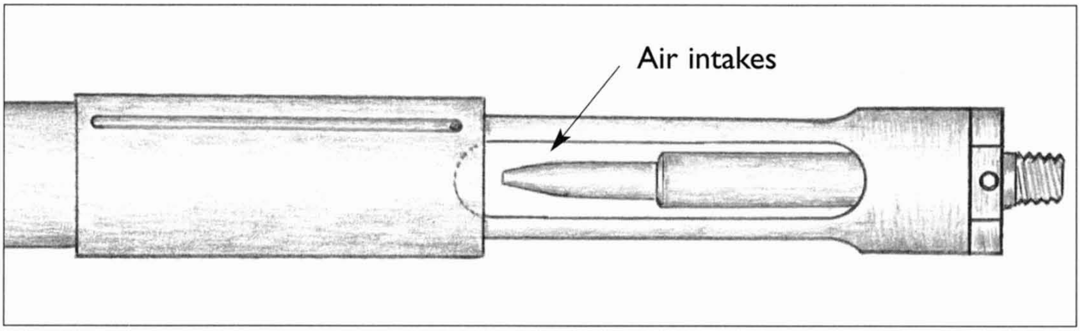


Fig. 2-6 The typical slotted tube burner; while the choke sleeve creates a square configuration at the forward end of the air slot by covering its rounded end, the back of the opening is still rounded. This will create drag by forming vortices.

The slots provided a larger opening in a given area than could a row of holes, but this was a minor advantage. The real improvement was the reduction in air turbulence caused by all the round surfaces in a row of holes (air passing through a round opening will tend to rotate, creating vortices). This form of air turbulence creates a lot of drag. Some turbulence can help overall burner performance by promoting better mixing of the fuel and air. But, since the row of holes creates most of the turbulence behind the gas stream it does little to promote mixing, while doing much to decrease airflow.

Drilling the slots leaves them with rounded ends. The shape of the rear end has less effect on performance than the shape of the forward end. Positioning a sliding choke so that it covers the rounded end of a slot when the choke is fully open will accomplish a similar result as squaring the opening's end; however, drag does more than reduce the amount of entrained air. It also decelerates the gas/air mixture. Many slotted burners can entrain sufficient air to create a neutral flame, but the increased acceleration that squared and beveled ends add is critical to achieving total primary flame combustion (see in Chapter 3).

Short and wide air openings tend to give a more powerful performance than long narrow openings. This can be used to enhance or tame burner performance as needed, just as with choke direction and accelerator position.

Chokes

The choke is made up of two parts. A choke sleeve, the movable part, limits airflow

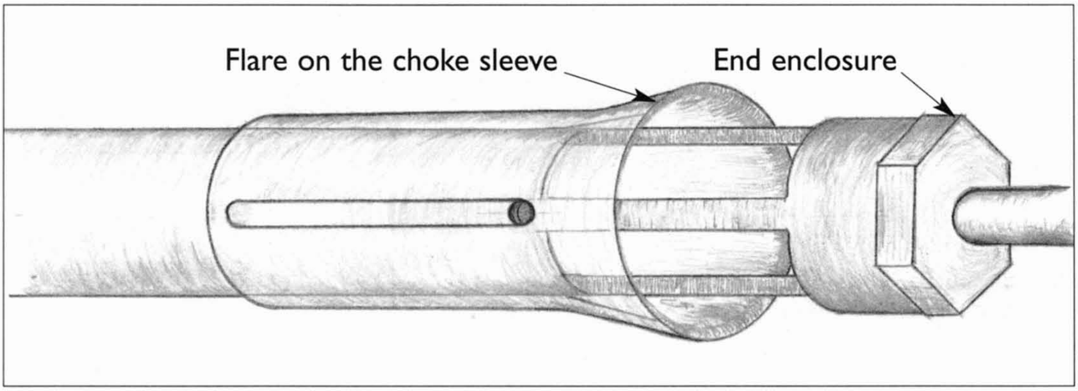


Fig. 2-7 A flared choke in a fully open position, funneling the incoming air stream into the burner tube. The forward end of its flared portion is even with the front of the air openings.

to the lateral air intakes on the burner's mixing chamber. The intakes and sleeve work together forming a choke. A thumbscrew locks the sleeve in place.

The flared choke Fig. 2-7 increases performance by helping to accelerate incoming air. A flared choke's funneled section always remains in the best position to affect incoming air, regardless of where the choke sleeve is set.

Nozzles

The burner nozzle serves several functions. By creating a sudden expansion at the end of the burner tube, it reduces flow speed. Otherwise, the gas/air mixture would tend to blow the flame right off the burner's end. The nozzle can be moved on the burner tube to vary the amount of its overhang. This changes the width to length ratio, allowing the nozzle to vary the amount of its impedance.

At the same time, the nozzle's greater diameter provides a large base upon which the flame can establish itself. The wider flame is shorter, keeping unburned oxygen further from your work. This is an important consideration in preventing oxidation of the material being heated once the nozzle has warmed up, and it has a tendency to automatically cause re-ignition should the flame blow out.

Some nozzles should have a taper and a step. A shoulder in turned flares or a spacer in forged flares generally forms the step. It should increase the width of the opening to at least 1/4-inch all the way around the burner tube's interior diameter, no matter what the thickness of the tube's material. Burners can run fairly well with just the step, but some run much better with a taper of 1:12 included, while others should not be flared; it depends on the construction of the burner.

Number 316 stainless steel is recommended for burner nozzles, because the hot gas will rapidly corrode mild steel. However, plain steel can take several hundred degrees higher temperature than most SS can. The nozzle can be protected from corrosive gases if it is painted with a protective ceramic coating such as ITC #213 or boron nitride (see Resources). So-called machinable steels must be avoided because of their lead content. They are not commonly found outside of a machine shop and may be identified by their unusual softness, which is about the same as brass.

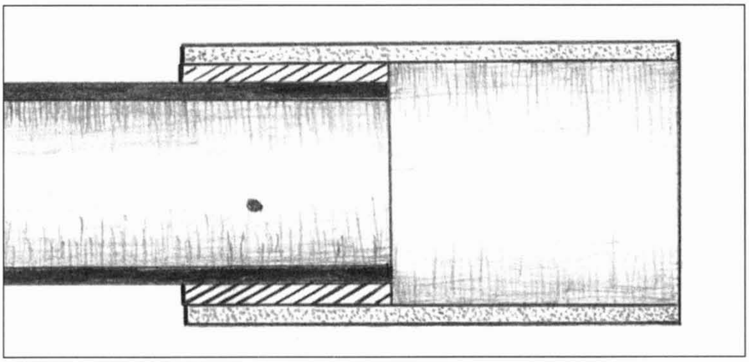


Fig. 2-8. Straight nozzles can be used with a spacer. They often require SS tubing instead of pipe sizes in order to attain the right ID. These nozzles also need a fast moving gas/air mixture.

The flare shape can simply be cast into the burner entrance when building a furnace with a poured refractory. Use the 1: 12 taper at its end, and make the whole length of the opening in the larger nozzle diameter, both to act as a "step" and for clearance. Without the increased diameter of the opening, the different coefficient of expansion would cause the steel burner tube to crack the furnace's refractory.

Do not attempt to replace the fiber lining in a forge with high temperature poured refractory walls in order to cast the flare. Furnaces have to be built this way, but fiber is a much more efficient insulation for forges. The flare should be cast as a separate burner port (see Burner Ports in Chapter 6 and 9).

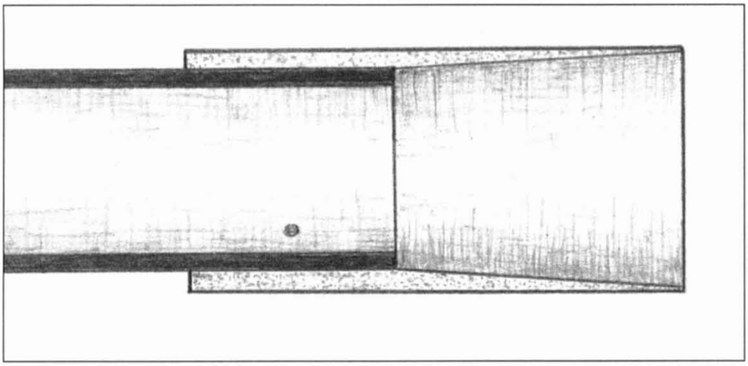


Fig. 2-9 Cutaway view of tapered nozzle; lathe turned for accuracy, leaving forward end thin.

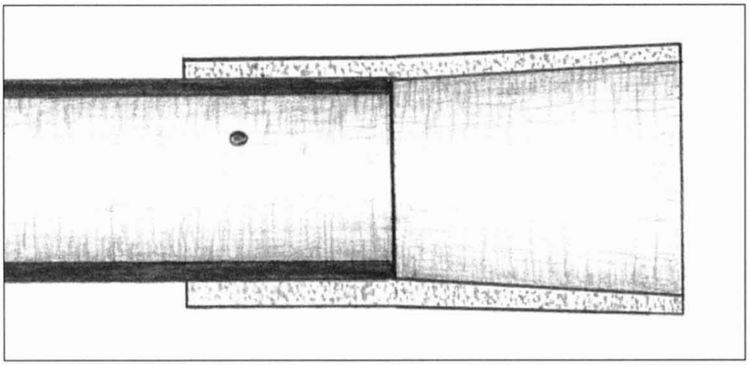
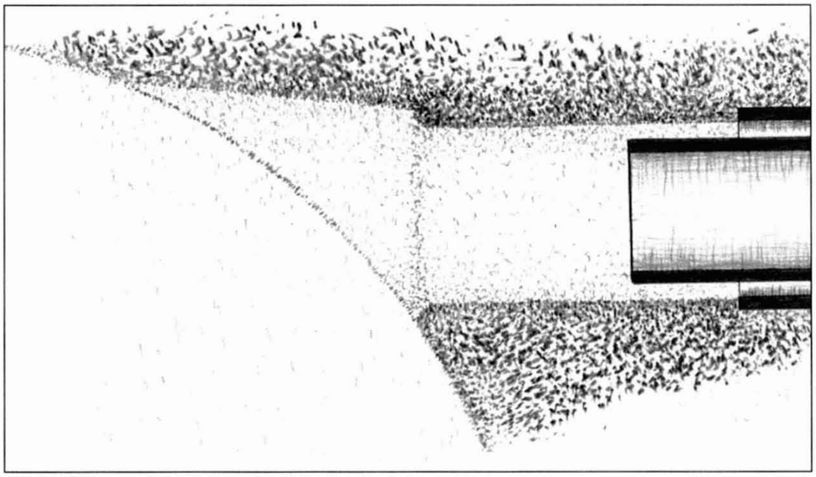


Fig. 2-10 Press formed tapers avoid thinning of the nozzle end, but can be out of true if not carefully made. Note the single set screw shown penetrating both parts to permanently secure the nozzle after the burner is tuned.

Fig. 2-11 Cutaway view looking down into a furnace shows the burner tube kept centered in a tunnel within the casting. The burner extends beyond the surrounding collar, which remains well behind the flame so that it does not expand with heat, breaking the refractory. The greater diameter of the tunnel acts as a nozzle. Beyond this "nozzle" area the refractory expands out of the way of the flame path in order to avoid overheating.



End enclosures

These assemblies (see Fig. 2-7) hold the gas accelerator in place. Some examples employ a movable steel bushing, which allows the accelerator to be aimed. Others hold the bushing centered in a bell reducer or pipe cap. All of them enclose the end of the mixing chamber. Surprisingly, a burner with a wide-open end on its body will not perform as well as one with lateral air intakes; however, even with lateral intakes an open end on the mixing chamber will hurt overall performance rather than enhancing it.

3

Building the 1/2-inch Burner

The first burner shown in this book is the 1/2-inch hand torch. It can be built with a minimum of tools. Due to its power, it will be useful in building other burners. After its construction, you may wish to change the plans on some of the larger burners to conform to what you learn during this burner's fabrication.

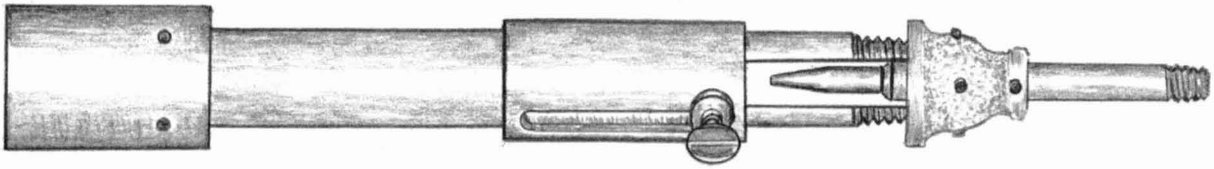


Fig. 3-1 The 1/2-inch burner or hand torch

The 1/2-inch burner makes an intense flame. The flame is far hotter than can be found on store bought propane torches (not including oxy-fuel torches). It is able to braze and heat tools for tempering. It can power a miniature forge or a small furnace for melting most metals. It can also be placed on a secondary fuel hose, and used to both ignite a forge and to sweat, or pre-heat your anvil.

This is a jet ejector burner. It uses a small copper MIG contact tip to strengthen the venturi effect that helps to entrain more air. The air to gas ratio is on the order of 28 parts air to 1 part fuel gas, instead of 20:1 achieved with previous burners. Of equal importance, is the fact that it can be almost perfectly tuned. This ability to be finely tuned, along with its tendency to run in a balanced fashion through a very wide pressure range, greatly exceeds previous tube burner models. It also saves fuel and can create more heat than an old style 3/4-inch burner.

The burner is compact and can be used with a miniature fuel hose, called a whip, making it very convenient for handwork. To make this whip, buy a 1/4-inch type "T" burning lead (oxy-fuel hose) at a welding supply store. Separate the fuel line from the oxygen line; they easily pull apart after their brass collars are filed off. The separated fuel line is highly flexible and lightweight.

There is a fairly involved construction plan given for the basic 1/2-inch burner, but someone with a low skill level and without a hand torch can fabricate it. This model makes a powerful and forgiving hand torch.

If you want every last bit of performance that this size burner can put out, add the advanced options. The options make a superb torch, but they require a higher skill level to construct than the basic burner. The advanced options also simplify your hunt for parts. Please read completely through Chapter 3 before deciding what plan to follow, as this will affect your choice of materials. Every burner in this book features a gas accelerator assembly that is built to a different plan. If you are hindered in finding a needed part for one plan, you may substitute another assembly.

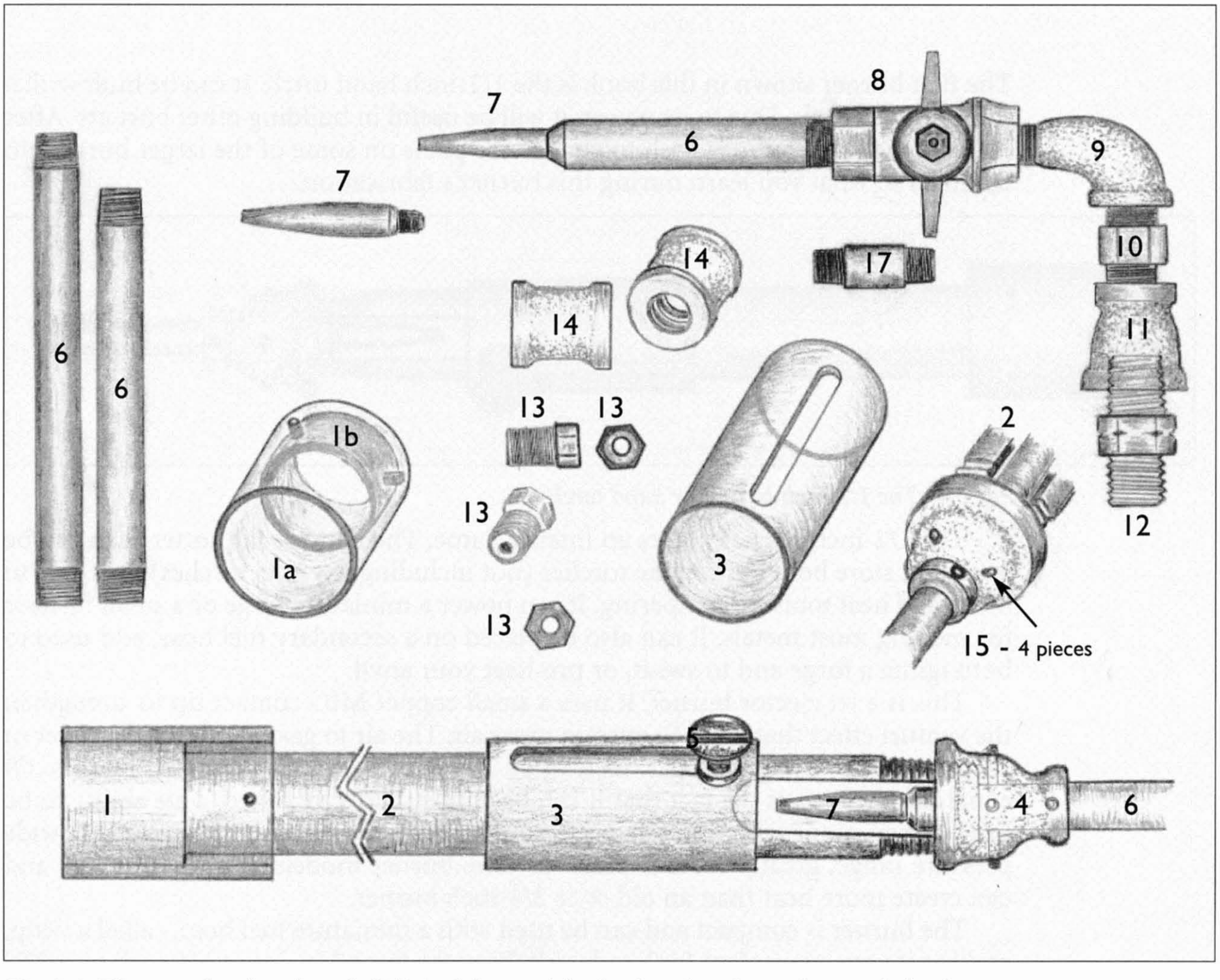


Fig. 3-2 The complete hand torch (1/2-inch burner) in the drawing shows the nozzle in place as part #1. This consists of the two parts, #1A & #1B, shown in perspective next to it. Part #3, the choke sleeve, is also shown in perspective next to it. Part #2, the burner body, is shown in perspective with parts #4 and #6 attached to it. Part #14 is shown in two views. Part #13 is shown in four views. Parts #6 through #12 make up all the gas fittings needed to feed gas from the hose and control its flow within the burner. Compare the numbers on the illustrated parts with their descriptions on the parts list.

Start with the basic burner by collecting the tools and parts needed. Before you begin buying the materials, it is important to understand that the sizes listed here are the parts' call-out sizes. That is seldom the same thing as their actual sizes. The differences have already been taken into account.[1]

Materials list:

(1a) #316 SS 1-inch Sc. #40 pipe 1 3/4-inch long [2]
(1b) 3/4-inch black wall #40 pipe 3/4-inch long
(2) 1/2-inch # 40 black pipe nipple 10-inch long
(3) 3/4-inch galvanized pipe 3-inch long [3]
(4) 1/8 NPT x 1/2 NPT bell reducer
(5) 1/4 x 20 thumbscrew (any length) and two flat washers [4]
(6) One 1/8-inch x 4-inch long brass pipe nipple and one 1/8-inch x 3-inch long nipple
(7) Two MIG welding contact tips for .023-inch welding wire size [5]
(8) 1/8 NPT gas rated ball valve
(9) 1/8 NPT 90° or 45° street ell (or regular elbow plus a second part #10)
(10) 1/8-inch short nipple (preferably a hex nipple)
(11) Two 1/8-inch NPT x 1/4-inch NPT bell reducers
(12) 9/16-18 LH thread to 1/4 MPT outlet bushing or a 3/8 flared fitting
(13) Two brass 3/16-inch inverted female nuts
(14) Two 1/8 NPT brass couplings
(15) Four #8 x 32 x 3/8-inch SS set screws [6]
(16) Four #8 X 32 X 1/4-inch SS set screws
(17) Two 1/8-inch X 1-inch long brass pipe nipples
(18) Regulator, hose, and propane cylinder

Tool list:

(A) 1/2-inch x 1/2-inch steel angle about six inches long [7]
(B) Hacksaw [8]
(C) 3/8-inch electrical drill
(D) A #3, #7, #29, two 1/8-inch, a 1/4-inch, 5/16-inch, "N", and letter "Z" drill bit [9]
(E) 4 1/2-inch angle grinder with thin cutting wheels and flap disk (see Resources)
(F) Locking pliers (Vise-Grip)
(G) Safety glasses
(H) Allen wrenches
(I) 1/4 x 28 starting tap, 1/4 x 28 bottoming tap, 1/4 x 20 starting tap, #8 x 32 starting tap, "T" tap handle, and tapping fluid
(J) 6-inch fine flat file
(K) 8-inch half round medium coarse file (optional)
(L) 1/4-inch or smaller rat tail file or round file
(M) Small center punch or prick punch and hammer
(N) Set of torch tip cleaners
(O) Dividers (optional)

(P) Marking pen
(Q) A small ball or cone shaped grinding stone (1/2-inch or smaller diameter)
(R) 1-inch brass or SS brush [10]
(S) 6-inch or 12-inch combination square
(T) Scribe
(U) Two sheets of #120 grit sandpaper
(V) Braze and flux (see Chapter 12)

Shopping for parts

Take this book along when you go shopping for parts. If you can't find a 1/8-inch ball valve, or if you have trouble finding any of the other parts, the text and drawings will allow a sales clerk to aid you in coming up with a workable alternate plan. For instance, you might want the ball valve to be in line with the accelerator, but everything else is negotiable, all the way back to the fuel hose. If you can't find a 1/8-inch ball valve, accept what you can get and readjust the parts list to make the different valve work. A look at Fig. 3-2 will make that simple for anyone working at the plumbing counter. If you can't find a part at your hardware store, look in the yellow pages under steam fitting, scrap yards, hydraulics, plumbing, and heavy equipment repair.

The bell reducer (part # 4) might not be available in 1/8-inch x 1/2-inch, but may be available in 1/4-inch x 1/2-inch. The addition of a 1/8-inch x 1/4-inch bushing will allow you to continue on with the project (the setscrew can be placed in one of the bushing's flats even more easily than in the side of the bell reducer's lip). The bushing can also be crosscut through its threads to become self-tightening (see parts #4B, and #19 shown in fig. 3-15). Or, a hex plug can be tightly screwed into the larger bell reducer as a spacer and then drilled through for the 1/8-inch accelerator pipe. These alternate plans will work just as well as the original. Even if you are shopping by mail, you can fax drawings and other information that will allow people, who know what is available in their parts inventory, to help you.

If you still can't find a needed part, then it becomes time to get creative. The publisher came up with his own unique solution to finding accelerator parts. His description follows: "On the accelerator I used a different method of assembly. I wrapped the MIG tip with a piece of 36 gauge brass tooling foil, 1/4-inch x 13/16-inch and slipped it in the nipple, then brazed it. I used self-fluxing brazing rod and it works fine."

You are given specific plans along with alternate plans, using different parts as a guiding map—not as a restraint. If finding the parts makes the plan harder to follow than striking out on your own, then become adventurous. You will also find parts and kit suppliers in the Resources.

In the introduction, you were promised that this equipment could be built with just hand tools. Lengthy instructions are given for accomplishing some of the drilling, grinding, and threading in this way. There is no need to bring any building experience to the project, but to use hand tools in the place of machine tools requires extra caution and attention to detail.

Now on to the fabrication of the burner.

1. The burner nozzle, parts #1a, #1b, and #16

Begin construction of the basic burner by making the burner nozzle. First, file the burrs off the 1 3/4-inch long stainless steel tube (part # 1a). This is the nozzle part that affects the flame.

Next, deburr the 3/4-inch long piece of 3/4-inch diameter steel pipe (part #1b), and file a small bevel on one outside edge. This is done to help it to slip inside part 1a. Hand sand the black varnish off its exterior, and file its protruding inner weld seam flat. When force-fit inside the nozzle tube, this part becomes a spacer, enabling the larger outside tube to fit on the burner's 1/2-inch pipe. Place the nozzle on the spacer's beveled edge and rotate it until the two parts come closest to matching each other. You can look down through the nozzle to compare it with the shape of the spacer and easily see where they make the best match. Set the spacer and nozzle on a flat surface with the beveled edge facing up. Hammer the nozzle down over the spacer until their two back edges are even.

Drill three holes through the nozzle and its spacer, about evenly separated and 1/4-inch from their back edges. Use a #29 drill bit. When you drill stainless steel it is important to use a new sharp bit and to be generous with the tapping fluid.

Thread the holes with the #8 x 32 tap. Again, it is necessary to use extra care and lots of fluid when tapping the SS, especially when using a small tap like this. Take your time and do the best you can to start the tap at right angles when it enters the hole. As soon as the tap starts to thread, stop and have a second look at the part. If the tap is obviously out of true, back it out and try again. You can restart the tap, as many times as needed because it will ream out all the scars from the false starts as it penetrates further into the hole. Remember to only turn the tap between an eighth and a quarter-revolution at a time. After each forward twist, reverse the motion enough to break the burr off of the forming thread, until you feel the resistance of the tap ease up. At that point your tap work can be accelerated. If you feel the tap start to tighten up, back it out and clean both the hole and tap before trying again. It isn't a tragedy to break off a tap inside of the nozzle. If this happens, place another hole near the first one and try again. Don't try to reuse the broken tap; throw it away and buy another one.

The tap might be broken off in the hole late in the threading process so that it protrudes into the interior of the nozzle. If this happens, use a small round rod (a nail with its point filed flat, etc.) and a hammer to rap gently against the side of the piece of broken tap. With luck, it will loosen sufficiently to allow you to back it out (reverse direction of turn) with needle nose pliers. In that case you can use the original hole. If the broken tap can't be loosened and backed out, use the same small rod with a hard rap to break off the interior protrusion. Finish removing the fragment from the nozzle's interior with sandpaper wrapped around the rod as a file.

Deburr the inside of the threaded holes and run the set screws into them. Keep the set screws away from the inside edge of the holes so as not to ruin their sharp faces if you need to file the spacer's inside diameter later.

The setscrews used in the nozzle are the only ones that are left with sharp ends. The rest have their ends filed smooth. Otherwise they would badly scar the accelerator's gas tube, complicating your efforts to maintain a good fit. Before going on with the burner construction, you should remove the sharp faces from the rest of the set screws. To do this, place the screws on the end of an Allen wrench to hold them in position; then gently sand their sharp faces off by running them back and forth on sandpaper; or run a fine grade flat file across them.

2. Preparing the burner body, part #2

The next step is to prepare the body of the burner. Begin by cutting the thread off one end of the 1/2-inch x 10-inch pipe nipple (part #2). Next, use the angle grinder and flap disc to sand down the pipe to a polished finish from the cutoff end up to the beginning of the thread on the other end. The varnish must be removed along with the rough surface irregularities. File the internal burrs out of the cut-off pipe end for good laminar flow. File the internal burr left by the pipe-threading machine out of the threaded end in order to help provide enough room for the temporary accelerator's coupling to fit within this space later. File the internal weld ridge flat as possible.

Place the nozzle on the burner body and rotate it until the two parts come closest to matching each other. Ink mark the parts to keep track of this position while you power sand the cutoff end of the pipe for about 1 1/2-inches to create a sliding fit with the burner nozzle. This is done with the angle grinder and flap disk. Be sure you have read the grinding directions given in Chapter 1 before starting.

Slide the nozzle onto the pipe up to where the inside edge of the 3/4-inch spacer and 1/2-inch pipe are even (as shown in Fig. 3-1). Twist the nozzle until it binds on the pipe, but do not tighten the three setscrews (twisting the nozzle usually forces it into parallel alignment with the pipe). Once you are satisfied that these parts are ready to go, remove the nozzle. Do not mount the nozzle on the burner until you begin brazing.

3. Making the basic choke sleeve, part #3)

Before you can do anything more on the burner body, make the burner's choke sleeve. This can be done with either a slotted part or by threading a hole in the sleeve for the thumbscrew. The threaded hole is easier to make and permits full opening with a shorter choke sleeve on the flared choke, but the slotted part is smoother operating. To make a threaded hole, measure 1/2-inch from the choke sleeve's forward edge. Then punch-mark and drill a hole with the #3 bit. Now thread the hole with the 1/4 x 20 tap. It will be necessary to file down the inside of the weld ridge in the pipe because you are not placing a slot where it is, but you can skip "Step 5" (installing the thumbscrew in the burner body) as you are placing it on the choke sleeve. If making a slot, use a piece of 3/4-inch galvanized pipe, 3-inches long, and file its interior until it slides freely on the burner (after making the slot). This is simple work as galvanized pipe often has a larger inside diameter than black-wall pipe, and the layer of galvanizing is soft.

Mark a straight line on the 3/4-inch x 3-inch galvanized pipe. Lay the line out over the pipe's weld seam in order to reduce your internal file work. The small 1/2-

inch x 1/2-inch angle held with its "toes" (edges) against the pipe makes a good guide. To use it with a scribe, place one edge close beside the layout mark, but not over it. Move the scribe down the length of the guide. Be careful not to change the angle of the scribe in relation to the edge as you create the parallel line.

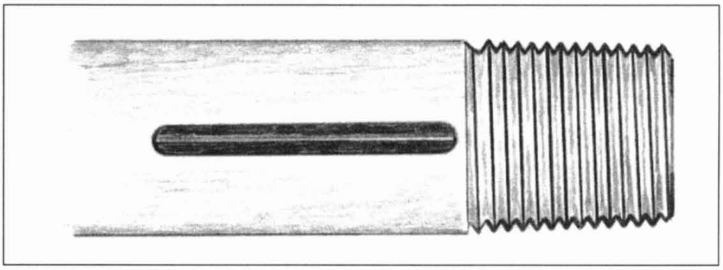


Fig. 3-3 The dark area represents the pattern of ink left when using the slot on the choke sleeve as a template. The light line in its center is made with a scribe.

Measure 1/4-inch in from the pipe's ends, and center punch. Continue marking and center punching at intervals of 1/4-inch, and then drill 1/8-inch pilot holes. Enlarge the holes to 1/4-inch. Grind and/or file into a smooth sided slot. Check the slot with the thumbscrew to make sure of a loose sliding fit. Clean up the internal burrs and file down the 1/8-inch of internal weld seam that remains beyond the slot ends. You can use the thin grinding wheel to quickly remove most of the material between the holes, but avoid trying to grind all the way to the slot ends; that seldom works out well. Remember to secure the part in a vice before trying this (read cautions about handling grinders in Chapter 1).

Now sand and file both the choke sleeve and the burner tube until the sleeve will slide freely. This amounts to more than half of the burner tube's length. Remember that both of these pieces of pipe are out of round. Begin the fit by revolving the choke sleeve on the burner tube. Also, reverse the choke sleeve as you work in order to see if it mounts better in the other direction. This extra experimenting will save a lot of sanding work.

One thing that helps you to determine where to sand once the parts begin to fit together, will be the scratch marks which the choke sleeve leaves on the polished tube everywhere that it binds. The more you look for these indications, the less sanding you will end up doing in order to achieve a good sliding action.

True up the back face of the choke sleeve. Compare it with the Combination Square to check it. Now slide the sleeve unto the threaded end of the burner tube with its trued end facing the thread.

After you find a place where the choke sleeve slides freely, use the ink marker to make a line down the length of the choke sleeve's slot while it is sitting in this area. Scribe a line from the thread down through the middle of the inked line. Leave the ink to remind yourself that this isn't one of the four lines for the rows of holes.

4. Preparing the 1/2-inch to 1/8-inch bell reducer, part #4

It is necessary to true up the forward edge of the lip on the bell reducer's large end. This is needed in order to provide a proper seal when the choke sleeve rests against it. It also improves your ability to drill the hole for the accelerator true. Screw the bell reducer onto the burner tube and mark its high areas while the trued-up end of the choke sleeve rests against it. Grind or file away any high spots, while frequently reassembling the parts for comparison. Place the bell reducer on the sheet of sandpaper to finish flattening its face.

Now, use a "z" size drill bit to enlarge the threaded hole on the reducer's small end to hold the accelerator. Place a chair or five gallon bucket on the floor on which to sit, clamp the locking pliers around the bell reducer just behind the large lip, and place the reducer on the floor in front of you (the locking pliers will be set at a slight angle). With one foot on the pliers and the drill bit resting on the reducer, position the drill motor as near to vertical as you can while sitting leaning forward over your work. Rest your arms on your legs. Gently enlarge the existing hole. You will be able to feel the point where the drill bit penetrates the material's far side in time to stop before it drills into the floor. Having your body braced in this position will give you surprising control over the drill's aim and a good brace against kickback when the bit reaches the far side of the existing hole.

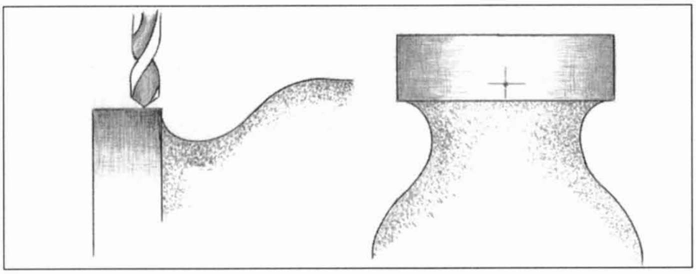


Fig. 3-4 Note the edge of the drill bit is even with the lip's edge, in the left side of the drawing. So, the bit's tip will scratch a line at the proper place for center punching, as is shown on the right side of the drawing

Next, punch-mark a place in the side of the lip on the reducer's small end for a setscrew. Use the #29 bit and the #8 x 32 tap to thread the hole. When you look at the drawing, notice that the setscrew is placed off-center (into the forward edge of the bell reducer's lip). This is done to insure enough room to keep the screw away from the lip's back edge. Also, make sure the hole is placed far enough back from the forward edge so that the drill bit can run true. To do so, place the #29 drill bit on the bell reducer so that the bit is just back from the lip's forward edge and use it for a scribe; then punch-mark your hole over the scratch mark. Doing this will keep the bit far enough from the edge of the lip to ensure that it doesn't run off to one side. The larger size of the tap thread will still follow the hole even though it runs into the curve beyond the lip.

By screwing the reducer onto the burner tube you can again use your foot to trap the part while sitting over it in a chair. Even with a small hole, the leverage and control this method gives you is good. If you temporarily slide the nozzle back onto the burner tube while you drill this hole, it is easier for you to keep the drill aimed at right angles with the reducer.

5. Installing the thumbscrew in the burner body, part #5

The time has come to permanently mount the choke sleeve. Therefore, place the sleeve on the 1/2-inch pipe, centered over the ink line with its squared end against the bell reducer. The reducer should be snug but not screwed down completely tight. Scribe a cross line in the center of the forward end of its slot for a thumbscrew hole.

Remove the bell reducer and choke sleeve. Center punch the mark, drill a pilot hole with a 1/8-inch bit, and enlarge the hole with the #3 bit (use the same control method as before). Now, thread the hole with the 1/4 x 20 tap. Clean up the burrs, inside and outside of the tube, with files. Re-thread the hole (this is called chasing the thread). Now re-file the hole. All these steps are needed to get a smooth sliding action on the choke.

Reassemble the choke and tighten the thumbscrew. One or two small flat washers are used with the thumbscrew to create a shoulder. This helps to more effectively lock the choke. Count the number of excess threads inside the burner tube. You must remove the excess thread. To do so, clamp the thumbscrew in the locking pliers, run a 1/4 x 20 nut down to where you have determined your thread length should end and grind off the excess. Afterward, unscrew the nut and file the burr off the end of its thread. You can use the half round file's edge or the miniature flat file in the tip cleaner set to remove this burr. Reassemble your parts, tighten the thumbscrew, and file off any excess thread remaining inside the burner tube.

6. Laying out the air openings, part #2

Slide the choke sleeve all the way forward (toward the nozzle), lock the thumbscrew, and scribe a line around the burner tube at the sleeve's back edge. Now slide the sleeve all the way back. Screw on the bell reducer until it touches the sleeve. Use the ink marker to make a line on the thread where it meets the lip of the bell reducer. Remove the reducer and the choke sleeve.

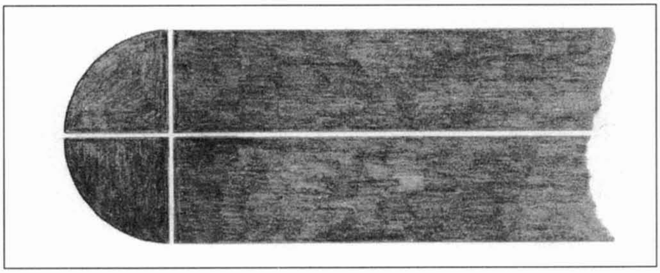


Fig. 3-5 The forward end of the inked area as it appears with the choke sleeve against the bell reducer and the crossing line scribed for the punch mark.

Cut a piece of paper about three inches wide and wrap it around the burner tube. Mark the point where it overlaps itself. Draw a line on this point at a right angle; cut off the excess paper and then flatten it out on a table. Use dividers or a tape measure to find and mark four equal spaces, beginning on the paper edge (the edge, a mark, a second and third mark, and finally the other edge). Mark a spot halfway between an edge and the first line on the paper. This spot will be centered over your scribed and inked line on the pipe. Mark the four places. They will become the centerlines of your air openings. Replace the paper around the pipe and transfer your marks. Check to make sure the spaces are equal and then scribe the other four lines.

The ink line represents one of the four ribs that will be left between the air openings. It is the only important rib because the slot in the choke sleeve slides over it.

Therefore, it is necessary to keep this one rib wider than the width of the slot so that the burner can be sealed if it is used in a forge. It isn't as important if the other ribs or the air openings between them end up imperfectly proportioned.

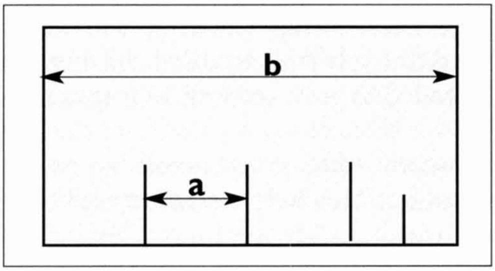


Fig. 3-6 Centers for the air openings are laid out on a paper template. It is cut about 1 1/2–inches wide. Line "b" is about 2 5/8-inches long. The three "a" lines divide the paper into four equal spaces. They should end up about 13/16–inches apart. The short line is the centering line, and is placed over the scribed line of the inked area, which marks the choke sleeve's rib. The paper's two edges come together, forming the fourth line.

The other four scribed lines now get cross lines marked at 1/4-inch intervals all the way from the first scribed crossing line to the inked line next to the bell reducer's lip. You will need to start by grinding a parallel groove in the thread. It should be deep enough to allow center punching. Afterward, reestablish the scribed line through this area, on all four of the parallel lines for the air openings. Remember to leave the inked line for the choke sleeve rib alone.

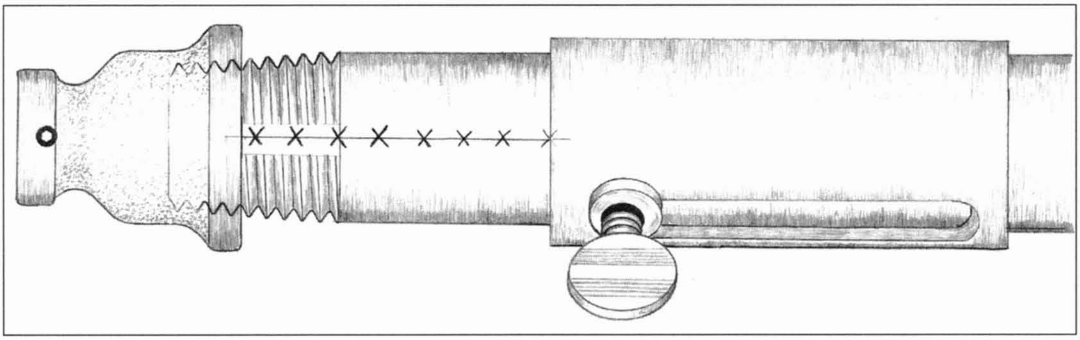


Fig. 3-7 Shows the cross marks every 1/4-inch. Note the bare area in the center of the pipe where the threading has been ground flat and scribed again. Be sure to file off the burrs created by the grinding before screwing the bell reducer back onto the thread.

After scribing the threaded area of the four parallel lines, measure and scribe crossing lines every 1/4-inch. Replace the choke and use it to transfer the crossing lines from the layout on the first line to the other three. Remove the choke and punch-mark all the crossing lines (including the first scribed line and the inked line).

7. Making the air openings, part #2

Drill a 1/8-inch pilot hole in each mark. You can put your foot on the burner tube to trap it on the floor for drilling from your chair. However, stand up in order to put greater weight on the part before enlarging all the holes to 5/16-inch. If you have had trouble keeping your punch-marks in a straight line, drill 1/4-inch holes and file them out to 5/16-inch afterward. Clamp the part securely to a table or in a vice and use the thin blade in the grinder to begin turning the rows of holes into slots (remember not to get over ambitious with it), or use the rat-tail or round file between the holes. Finish smoothing the sides of the air openings with a flat file.

The ribs, which remain between the slots, will not withstand physical abuse. Even the stress of screwing the bell reducer back into position could bend the tube out of alignment. Always use a bar, pushed through the slots like a spanner wrench, to hold the burner tube. It should be as close as possible to the threaded end. Take out the "spanner wrench" to unscrew the reducer on later.

Screw the bell reducer snugly into the pipe and file the back end of the air openings even with it. Remove all burrs from the slots. The placement of the choke covers the round forward ends of the slots, and with the back ends filed square, the slots effectively become rectangles. The importance of the rectangular configuration, rather than slots can't be overstated.

8. Placing the aiming screws, part #15

The accelerator in this burner can be aimed. If you drilled the size "Z" hole perfectly true to the burner's axis, you still need to change the aim of the accelerator to get the best flame characteristics at different gas pressures. To install the aiming screws, drill four #29 holes and tap them for #8 x 32 thread. Space them equally around the bell reducer's side and as far back from the lip of the large end as you can get without encountering the curve of the bell shape. This allows the setscrews to clear the threaded end of the pipe. You can use the air slots on the burner tube for an approximate positioning and then refine the hole placement with the dividers or a tape measure. Drill and thread these holes and place the longer setscrews in them. This allows you to aim the accelerator perfectly.

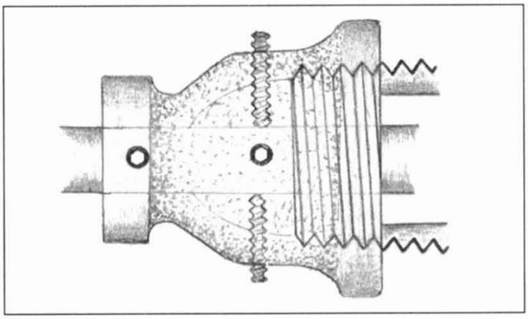


Fig. 3-8 Four of the locking set screws (part #16) are shown in the smaller lip), and three of the four aiming set screws (part #15) are shown just below the curve in the bell shape. Note the way they trap the accelerator's gas tube. By moving them a small amount, the tip of the accelerator can be aimed anywhere within the interior of the burner body.

While drilling through the bell reducer you may encounter something unexpectedly hard near the place where you thought to finish the hole, which is the steel pipe thread. Sometimes a pipe thread runs undersize because the dies in the threading machine weren't set quite right. This will allow the pipe to thread further into the female fitting then it was designed to do and thus into the area where you are drilling the holes for your aiming screws. Simply stop drilling, unscrew the burner tube, and power sand the 1/2-inch pipe thread back to where it doesn't encounter your hole. Then use the flat file to remove the burr from the thread end and screw the parts back together. Don't try running the threaded holes through the pipe. Even if you succeed, your fit-up would become a nightmare afterward.

9. Making the temporary accelerator, parts #6, #13, #14, and #17

By building this accelerator, the hand burner can be used to finish its own construction, ending the need to buy a commercial propane torch and MAPP gas bottle. Also, since the hand burner will put out considerable heat (even with the temporary accelerator installed), high temperature silver braze can be easily used. The extra brass 3/16-inch inverted female nut and 4-inch pipe nipple can be recycled into an accelerator for the next burner after the first accelerator is completed.

The length of the brass nuts insures that the hole and its thread will have a good chance of running true. The length of the nut also promotes accuracy when the parts are brazed together. It is important to have the contact tip installed in line with the accelerator pipe, because bending the part into position afterwards isn't desirable when its threads must be able to seal.

Begin by screwing the 1/8-inch x 1-inch pipe nipple into the 1/8-inch brass coupling to make a drill jig. Next, screw one of the two 3/16-inch inverted female nuts into the coupling's other end and drill a hole through the nut with the parts held in a vice or in locking pliers.

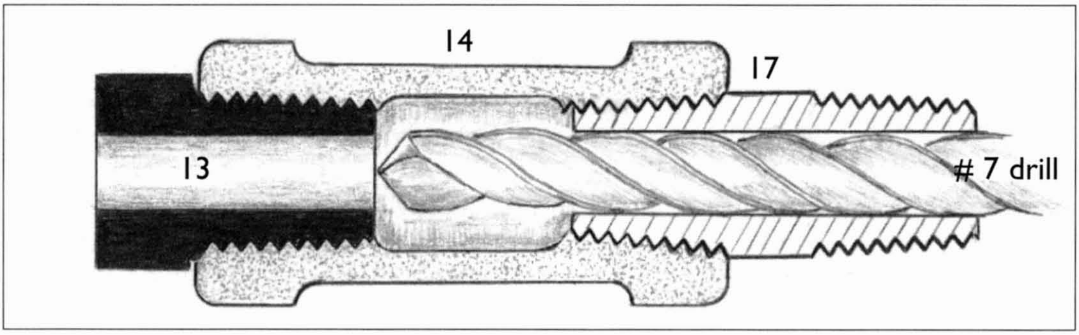


Fig. 3-9 Numbered parts for drilling with the fixture.

Use a #7 drill bit for the hole and run it into the nut from the far end of the 1-inch nipple. This further ensures an axially true hole. Remove the nut and repeat this process with the second nut. Now use the 1/4-inch x 28 tap and run it though the nipple to thread the nut. Do not use tapping fluid (because that would interfere with soldering later). You must either screw the nut very tightly unto the coupling or clamp the locking pliers gently unto it instead of the coupling to hold the fixture for drilling and tapping. Otherwise the nut will tend to unscrew itself during the work.

Remember to only turn the tap between an eighth and a quarter-revolution at a time. After each forward twist, reverse the motion enough to break off the burr. Gently tapping the hole this way, and completely backing the tap out if it starts to feel like it's binding, will guard against breaking it off in the dry thread. You may have to use a bottoming tap to complete the threading of this part.

Blow the metal shavings out of the nut and remove it. Place Teflon tape on the other nut, insert it in the coupling, and repeat this process. Leave the second nut in the coupling. Place the nipple into the drill motor. Spin the whole assembly under a file or hand grinder to reduce the coupling's diameter until it will fit easily into the

1/2-inch burner tube. Remove the 1-inch pipe nipple. Blow the metal shavings out of the nut and coupling.

Use a 4-inch brass pipe nipple, instead of steel, for the accelerator's gas tube because it has closer tolerances, but it still may not fit easily into the bell reducer's hole. If it doesn't, spin it in the drill motor using sandpaper. Keep checking for a sliding fit as you sand the part. Once the nipple fits into the bell reducer, wrap Teflon tape on its thread and screw it into the coupling. Place Teflon tape on the threads of the Tweco contact tip and screw it into the 3/16-inch inverted nut.

It is necessary to use a sealant on all the pipe threads, even though this is a temporary part. The slightest gas leak will catch fire. On the contact tip this would destabilize the flame, and anywhere else on the burner the gas will ignite in a startling way. This will cause you to flinch, and flinching when you are aiming the torch is never a good idea.

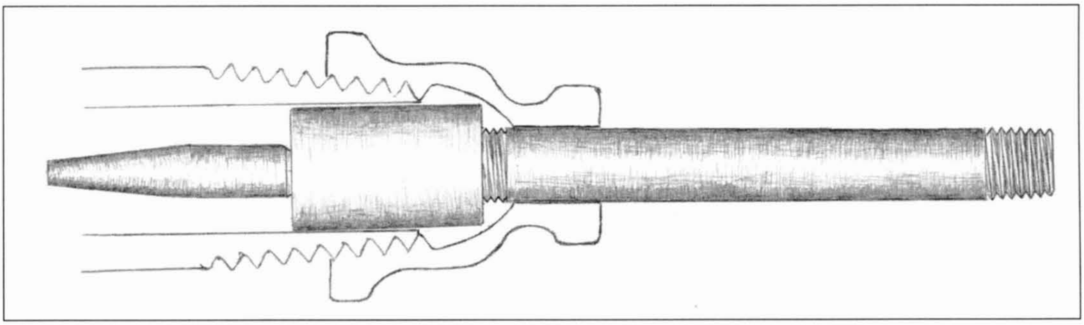


Fig. 3-10 This drawing illustrates how the temporary accelerator tightly fits inside the burner (shown in outline) even after it is ground down

When the temporary accelerator is ready, unscrew the bell reducer and place the accelerator inside of it, with the contact tip placed as far back as the coupling permits. Screw the reducer onto the burner tube and barely tighten the locking screw. At this point, reinstall the burner nozzle.

The next steps of assembly use the process of brazing. For complete instructions and to better understand this technique go to Chapter 12, "Brazing".

10. Assembling the valve and hose fittings, parts #8, #9, #10, #11, & #12

Screw the ball valve onto the accelerator. Screw the street ell into the back of the valve and the 1-inch nipple into the ell. Screw the 1/8-inch x 1/4-inch bell reducer onto the nipple and the outlet bushing into the reducer. Use gas rated Teflon tape or sealant making sure to keep it away from the last two threads on the parts. The torch should now be ready to use.

So, try it out! Open the choke about a 1/4-inch, then set your regulator pressure to 4 PSI and ignite the hand torch. Open the choke all the way, and slowly increase the gas pressure. Because of turbulence caused by the temporary accelerator's coupling, you will experience barely acceptable performance, but it will still be more than hot enough to silver braze. On the other hand, because of the low performance, tuning isn't difficult yet. Play with the burner for a few minutes to become familiar with its performance.

11. Building the permanent accelerator, parts #6, #7, and #13

A pocket for the inverted nut is created in the 3-inch pipe nipple by drilling it out with an N size bit to a depth of about 1/2-inch beyond the thread. To do this, screw the other 1/8-inch coupling onto the 3-inch pipe nipple, and gently clamp the locking pliers onto the nipple. Clamp the part on the thread just beyond the coupling. Then screw the 1-inch nipple into the coupling's other end. Gently drill through the 1-inch nipple. When you feel the drill go through the 1-inch nipple's far end, stop drilling, and push the drill bit forward by hand until you feel it touch the end of the 3-inch pipe nipple. Mark the drill bit's depth and then add 3/4-inch. Make a second mark and continue drilling until the second mark reaches the coupling. Unscrew the 3-inch pipe nipple, and cut off the threaded portion of its end. Save the drilling jig for the second accelerator.

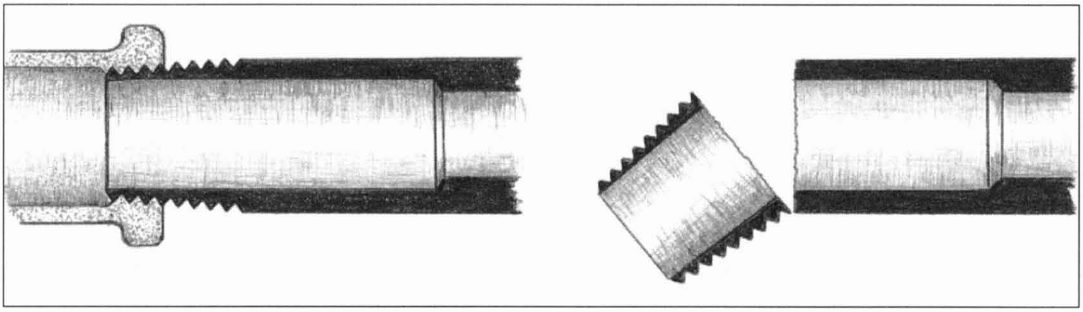


Fig. 3-11 The left side is the drilled out 1/8–inch pipe nipple, still screwed into the fixture. On the right, the thread has been cut away from the finished pocket.

Now the outside of the inverted female nut is turned down to fit within the "pocket" made for it in the end of the brass pipe nipple. Screw the second contact tip into the other inverted female nut, and then use it to hold the part in the chuck of a hand drill. Spin the part in the drill while holding a flat file against the fitting's

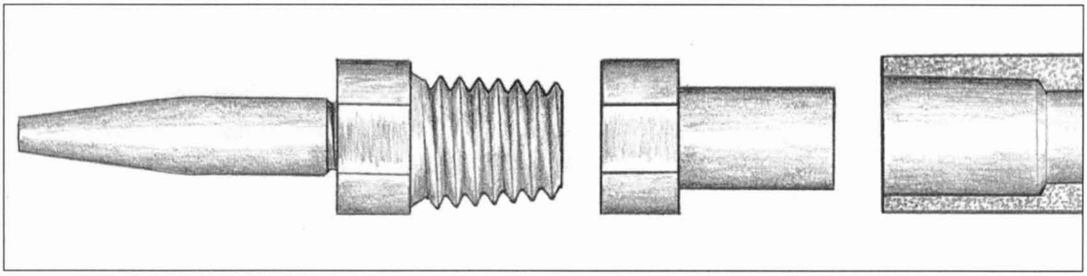


Fig. 3-12 The MIG tip is screwed into the nut on the left side of the drawing. The middle is the turned down nut which is ready to be inserted into the pocket in the gas pipe, shown on the right. The dark lines inside the pipe end represent the pocket.

threads. If your nut becomes loose, file on the other side of the part. Keep checking for fit in the pipe pocket until you have a snug fit. Use the "tooth brush" to clean the shoulder of the nut. Use pliers on the shoulder to unscrew it from the copper tip before releasing them from the drill chuck.

Flux the turned section of the brass fitting (outside only), making sure to keep the flux away from the end of the part. Insert the part into the brass pipe. If you need to press the parts together, remember to screw the other end of the pipe nipple into the 3/8-inch x 1/8-inch bell reducer first to protect its threaded end, and then gently tap the parts together.

Now silver braze the parts together. It is best to do this in the upright position, with the nipple temporarily screwed into the I/8-inch x 1/4-inch bell reducer (smear oil on these threads). The bushing can then be held in a vice or the locking pliers. After brazing, the part is chucked in the drill and spun under the file to remove any excess braze from the exterior of the pipe and to round off the fitting's hex faces. Then run the 1/4-inch x 28 tap into the fitting to chase (clean up) the threads.

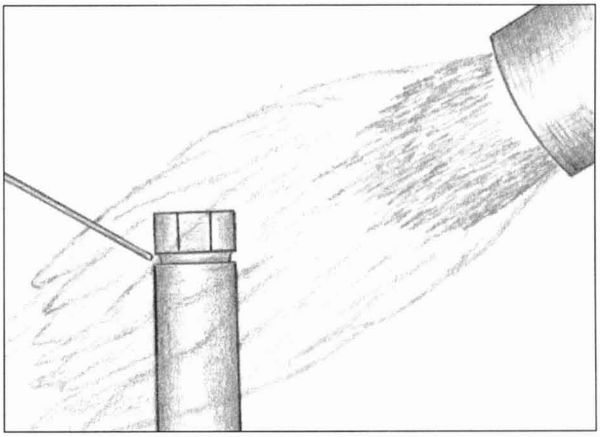


Fig. 3-13 Accelerator parts are silver brazed with a reducing flame. The primary flame is jagged and greenish tinged with almost no rear cone. The secondary flame is allowed to wrap around the heating parts, keeping oxygen away from them. The brazing rod is on the opposite side from the flame, which helps to draw the liquid metal completely around the joint as it flows toward the heat source. At this point, the flux has mostly bubbled away leaving only a thin coating of "glass" on the metal surfaces.

After removing the pipe from the drill, clean the flux out of it with a small drill bit (run with the drill motor reversed so it won't damage the inverted nut) or scrape with a round file. Blow any metal shavings out of the accelerator. Use Teflon tape to ensure a good seal and screw the contact tip into the accelerator pipe (keeping the tape away from the thread end). Performance of the torch will be increased if you bevel the shoulder formed between the contact tip and the larger diameter pipe.

Replace the temporary accelerator with the permanent one then recycle the spare parts into a second finished accelerator. When you drill the 4-inch pipe nipple, mark it the same as the three-inch nipple. The extra inch of length will be useful in the 3/4-inch forge burner. Screw the first 1/8-inch x 1-inch pipe nipple into the other coupling and keep them both for tooling.

Tighten only the locking screw enough to keep the accelerator from moving while you test its position during tuning. Once you're satisfied with the position tighten further. Even with its face smoothed, the setscrew will tend to create a dimple in the brass pipe when fully tightened.

To check the accelerator's aim, turn the burner and view the tip through each of the air slots. Then hold the burner up to a light and look at the tip through the burner nozzle.

Aim the accelerator assembly by manipulating the forward ring of setscrews until the contact tip is axially true with it. Now tighten the four aiming screws to just snug. Tighten when tuning is complete.

12. Tuning

Tune burners in the open air. To see the flame, tune the burner in a shaded area; bright daylight can make the flame nearly invisible. Burners are more easily observed this way. The interior environment of the forge can not aid their combustion, so they will run better if placed the forge afterward.

Begin by placing the flare (see Step 14) at 1-inch of over-hang beyond the burner tube's end. Next run the burner at various settings while moving the flare back toward the burner tube's end (effectively shortening the flare stick-out) to find it's best setting and to familiarize yourself with it. This burner should run best at 1-inch of overhang. The accelerator is likewise moved back and forth to find it's optimal setting. It should run best if set with its tip about 1/4-inch back of the fully open choke.

Start the burner with the choke about 1/4-inch open and the regulator set at 5 PSI. After about a minute the choke can be opened more. After two or three minutes, the choke can be run wide open. The choke should be fully open while tuning the burner and only afterward used to fine-tune the flame characteristics for different pressure settings or for making a reducing flame during special applications.

This model has an adjustable aim for the accelerator. The flame characteristics can change drastically on this burner (especially at low pressures) long before a miss-shaped flame alerts you to a poorly aimed accelerator, so you must consider aiming to be one of the steps to tuning this particular burner. In the smaller diameter burners like this one, the best performance isn't always obtained by aiming the accelerator perfectly true. At some pressures you will want to aim the burner a slight angle for maximum performance. This can be understood with practice.

A greenish tinged flame is a reducing flame. This is several hundred degrees colder than a neutral flame, and because the gas isn't being completely burned, it is polluting. However, it can be useful to run a slightly reducing flame for short periods in order to help prevent oxidation of surfaces being brazed.

Tune the flame leaner and the inner cone becomes clear. The flame front is now a pale blue. This is the beginning of a neutral flame.

Now transfer your attention to the secondary flame. Tune a little leaner and the secondary flame reduces. With the advanced burner it almost disappears producing a high-end neutral flame that is as hot as a flame can be tuned with gas. You can make flames larger, but not anymore efficient. Flame shape will change according to gas pressure and the position of the accelerator, but the roughened wave front and blunted end (like the tip of a baseball bat) is typical for the advanced burners.

As the burner is tuned still leaner, the flame becomes a darker blue. This is the beginning of an oxidizing flame. It will tend to burn your work and is not as hot as the neutral flame. It will also produce carbon monoxide (although to a lesser degree than a reducing flame).

The flame is tuned by moving the choke for different pressure settings. After the nozzle heats up, this burner tends to run well, but you can still fine-tune it with the choke. Before the nozzle heats up it is easy to open the choke too far and create an oxidizing flame. Please note that if you include the advanced options, tuning characteristics will change drastically. The burner will no longer be as forgiving and will not tend to run in a balanced fashion by itself. You will have to pay close attention to choke position when you change pressure settings on the advanced burner. Don't be concerned about not being able to run the choke wide open at most pressure settings with the flared choke. It simply scoops up more air than it can use at higher pressures (unless it is used in a forge or furnace).

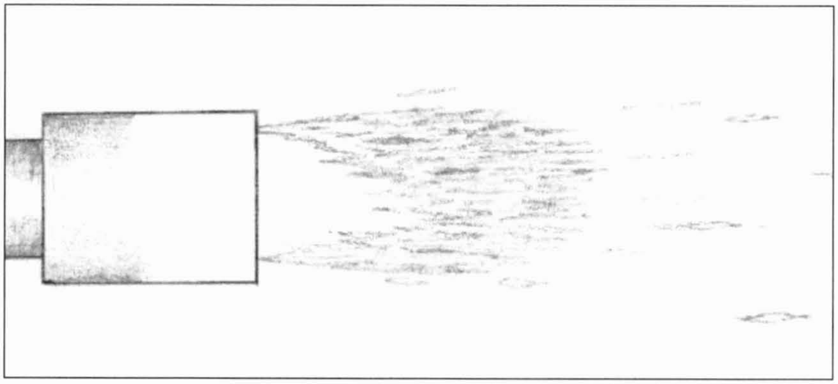


Fig. 3-14. A typical high-end neutral flame emerges from an orange hot nozzle; there can even be an orange envelope until the nozzle heats up. It is distinguished by a clear cone behind the jagged light blue flame. The jagged look comes from minor explosions ripping back and forth along the flame's wave front. A wisp of secondary flame and yellowish-orange flames winking out almost instantly is customary with the smaller burners.

Now see how far down you can run the pressure. After a few tries, you will note that below a certain minimum pressure range the burner's flame becomes feeble. All the jet ejector burners have a threshold pressure below, which they act like induced burners. What is important to understand about the threshold pressure is that the burners are not nearly as stable below it as they are above it. If you are using a single stage regulator, your system pressure will tend to fluctuate occasionally, and if you are running the burner below its threshold pressure it will falter. So, when you place the burner within a forge or furnace, remember to keep the idler adjustment above this minimum pressure (see Forge Idler section of Chapter 5).

The expansion of the heated nozzle is greater than the expansion of the air-cooled burner body. Inside a forge the difference is great enough to loosen the nozzle and allow it to slide off the end of the burner unless you severely over tighten the nozzle's setscrews. This is likely to damage them where they must be drilled out to change the worn out nozzle. Pinning the nozzle to the burner with an additional screw through all three parts is advised if you will be using the torch to power a Mini-forge or small furnace. Wait until you are thoroughly familiar with the finished burner to do this. Don't allow any protruding thread inside of the nozzle. If you are only going to use the burner as a hand torch, then snug the setscrews in the nozzle position that best suits performance and retighten them with the nozzle fully heated. To remove the nozzle, heat it up; this will relieve the pressure on the setscrews.

13. Advanced burner options

The burner you have just made is powerful and very forgiving in its performance characteristics. It can be made more powerful with some modifications the first of is to grind the excess lip on the large end of the bell housing down even with the rest of its body. Use the flap disk and revolve the burner under it by hand. Afterward, light the burner and note the increased performance.

It is a good idea to use a second bell reducer for the changes so that you can switch back and forth between the two parts, thus maintaining a wide range of burner performance. This also allows you greater accuracy and stability when spinning the parts as shown in Fig. 3-16.

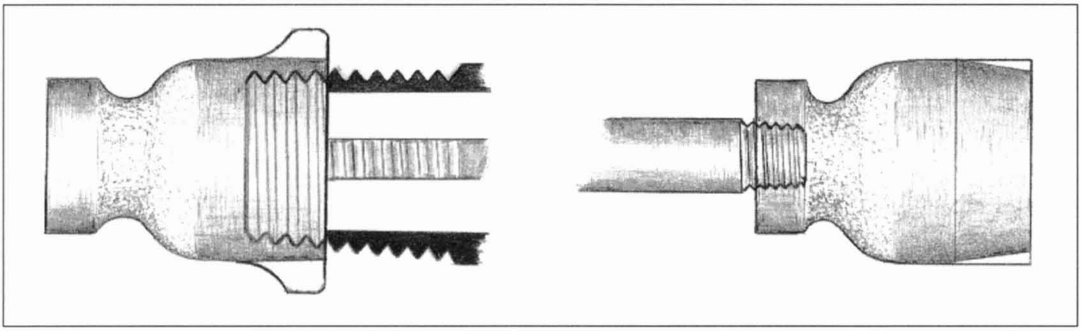


Fig. 3-15 Shows the second bell reducer with its lip flattened by hand grinding on the left side. The right side shows it with bevel, ground by spinning it while mounted on part # 17.

Next mount it on a spare pipe or use a second bell reducer (recommended). Remove the accelerator assembly and unscrew the reducer on the drill fixture assembly. Place them in the drill motor and revolve them under an angle grinder. Use the setscrews to adjust it until it no longer wobbles, then sand a bevel in the forward edge of the bell reducer where you just removed the excess lip. Both the removal of the "lip" from the bell reducer and the grinding of a bevel in that area help to increase airflow by streamlining the burner at the rear of the air intakes. Reassemble the burner and tune it again. You will notice that with each increase in performance, the burner becomes less forgiving about choke placement, which is natural.

Finally, build the flared choke sleeve and install it on the burner. You will notice another jump in performance and in touchiness. Also, the burner can once again be easily sealed at shutdown when used in a forge or furnace.

14. Forging a flare on the choke sleeve

This choke has a flared end. You can forge the flare shape on the end of 3/4-inch galvanized pipe or metal tubing.

If you use galvanized pipe, you must first heat it up enough to burn away several inches of coating before performing the forge work. This is done in order to avoid breathing the fumes from the burning zinc. Place a two-foot section of 3/4-inch pipe in a charcoal or wood fire (outside) and stay away from the fumes as the zinc burns off (although pipe is called galvanized, most pipe is actually zinc plated). Afterward,

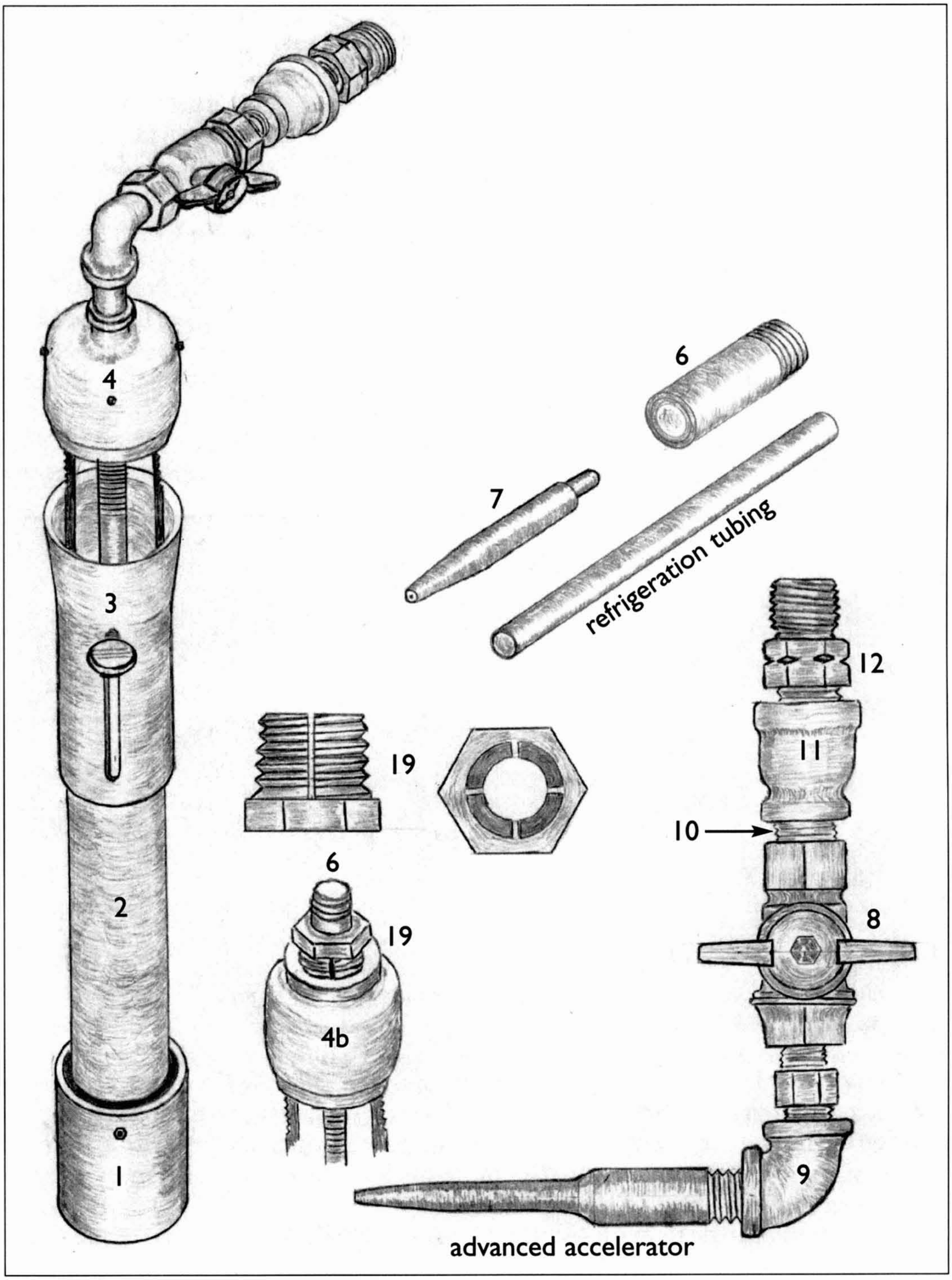

4
6
7
refrigeration tubing
3
12
19
11
10
6
2
8
19
4b
1
9
advanced accelerator

Fig. 3-16 Advanced burner drawing. The fabrication instructions for part #19 are given in Chapter 4, step 4.

brush and file any remaining plating from the pipe. Remember to thoroughly clean the inside also. Do not use black pipe for the choke. It can be much harder to get a sliding fit with.

Clamp a 1/2-inch or 5/8-inch round bar in the vice. File a mark on the top of the bar at 3/4-inch. Heat a short area of the tube's end and place it over the round bar, up to the mark. You can use a barbecue for heating if you haven't made the basic burner already. With a light hammer, tap the pipe on its side while revolving it on the bar. Try to create a flare about 1/8-inch to 3/16-inch larger diameter than the rest of the pipe.

Be careful when quenching the heated pipe, as it will instantly turn water into steam with a danger of burning you with a blast shot out of the pipe. You should let the pipe air-cool if you're unfamiliar with this process. If you are in a hurry and no one else is around, cool the hot end of the pipe into a slack tub and aim the other end away from the area. A hot blast of steam will shoot out.

A taper to the cross section of the metal wall will tend to form, making the flare thinner at its edge. This is fine. Cut the flared tube off at 3 1/2-inch that will become the choke sleeve.

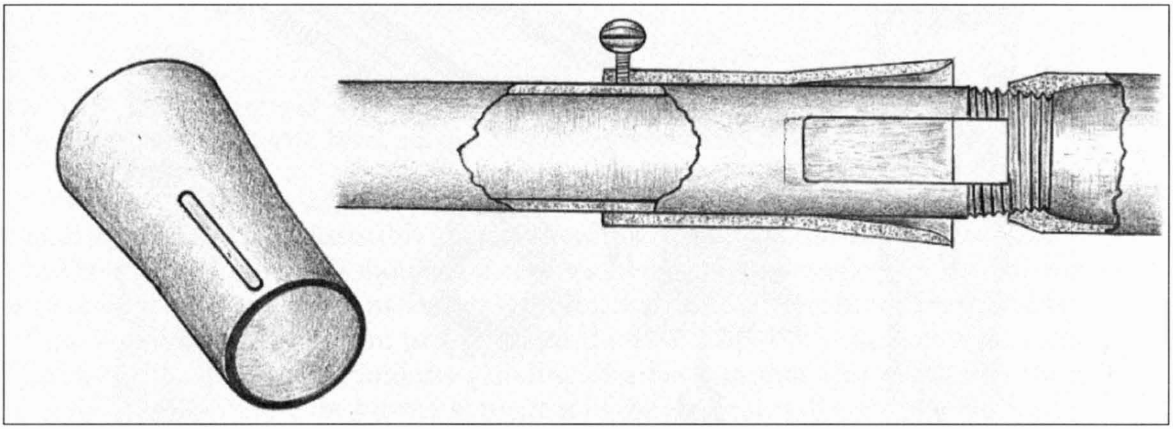


Fig. 3-17 At left, the choke sleeve has a slot. In the cutaway view on the right a thumbscrew is mounted in a threaded hole, and pressing against the burner tube wall, which is shown in cutaway. The bell reducer is shown cutaway, exposing the squared back of the air opening. Its forward end's bevel is shown in X-ray view. See Fig. 4-5 for comparison.

Mount the flared part, sitting vertically in a vice. File the lip of the flare even. Mount a grinding stone in the drill motor. Then move the part to a convenient angle and start grinding the inside of the flare reasonably smooth, ending with a rounded lip. Turn the part and grind out the whole inside of the flare, section by section. Remember it doesn't have to be perfect.

Use the small angle to mark a straight line on the cylindrical portion of the sleeve. Make sure the line is over the weld seam in order to reduce your file work. Measure 3/8-inch from the straight end and center punch. Continue marking and center punching at intervals of 1/4-inch along the cylindrical portion of the tube, stopping

1/4-inch from the beginning of the flared area. Drill 1/8-inch pilot holes and enlarge the holes to1/4-inch. Grind and file into a smooth sided slot. File the remaining areas of the interior weld seam flat.

The flared choke is employed to best advantage on burners that are used in forges and furnaces or when used with oversized nozzles. In other words, the flared choke is best used when maximum draw on the burner is more important than fine-tuning. Therefore, mounting the thumbscrew 3/8-inch from the forward end of the choke sleeve is recommended over using a slot because this option will allow the choke to fully open and close without extending the length of the choke sleeve (the flared section reduces the slot length). A longer choke sleeve would limit the depth that this burner can be placed within a forge or furnace too much.

The accelerator is positioned with its tip just beyond the bevel at the front of the air openings when using a flared choke sleeve. Temporarily remove the thumbscrew and slide the choke all the way forward to clear the intake area, then place and lock the accelerator in position. This puts the accelerator forward of the choke sleeve, even when it's in the full open position.

15. Advanced accelerator assembly

The accelerator assembly shown below is simpler to fabricate and easier to find parts for than any of the others. It is also shorter and powerful enough to allow the ball valve to be placed out of alignment for handwork, thus shortening the torch. A further advantage is its ability to bend. This ends the necessity for aiming screws in the bell reducer.

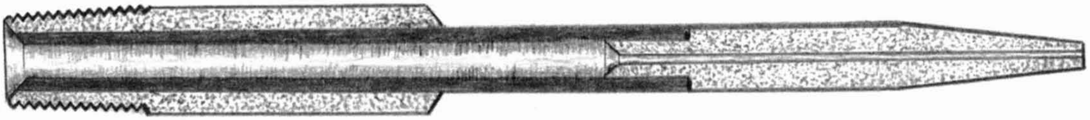


Fig.3-18 A cross section of the advanced accelerator. On the left is the cutoff 1/8–inch pipe nipple. Its forward end is beveled to increase air flow. The dark part in the center is refrigeration tube. It and the outer pipe have been beveled to increase gas flow. On the right is a tapered MIG tip with filed off thread, allowing it to fit within the copper tube.

However, brazing it requires a higher skill level than the other accelerators, and it is not as easily cleaned for maintenance. If the contact tip orifice is damaged in any way (for instance by being dropped), this accelerator might as well be thrown away. It is best used in smaller diameter burners like the hand torch.

Parts list

(4) 1/8 NPT x 1/2 NPT bell reducer
(6) 1/8-inch brass pipe nipple three inches or longer
(7) 1 1/2-inch long standard or tapered MIG contact tip for .023 or 6mm wire.
(18) About one foot of 1/4-inch copper refrigeration tubing

Tool list:

(A) Small pipe cutting tool
(B) 1/8 NPT die (recommended)
(C) Set of extra long torch tip cleaners (recommended)
(D) 3/16-inch or smaller round file (recommended)
(E) Pipe cleaners (recommended)

16. Fabrication, parts #6, #7, and #18

Begin by using a tightly rolled cylinder of sandpaper or a nail with sandpaper wrapped around it to clean the oxide film from the inside of one end of the 1/8-inch pipe nipple (the file isn't any good for this). Try for a depth of about 2-inches. Next, use the pipe cutter to detach a 1 1/2-inch long section from the sanded end. Do not saw the part. The deformation of the nipple and the internal burr left by the pipe cutter are essential to your construction plan.

Chuck the pipe and spin it under a file to form a partial bevel on the outside of the cut end. Now use the pipe cutter to separate a 2 1/2-inch long piece of the 1/4-inch refrigeration tubing. Choose a reasonably straight section of the tubing, but don't worry about whether it is perfectly true or not. Clean out the internal burr and sand the oxide film from one end of the I/4" tube to a depth of 1/2-inch. Then sand the complete outside length of the tube to prepare it for brazing.

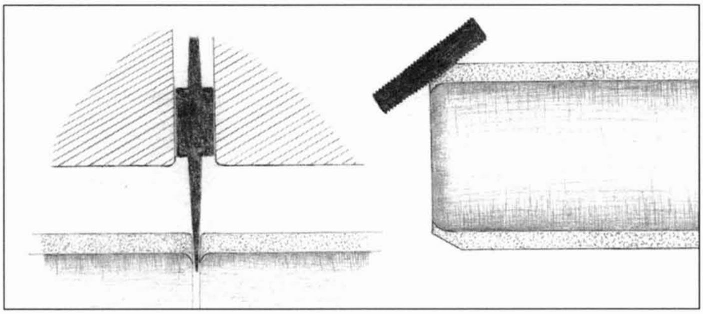


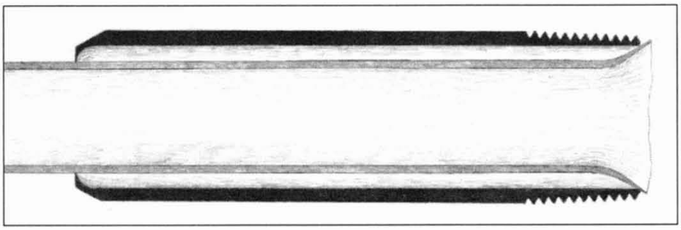
Fig. 3-19 The blade of the pipe cutter deforming the tubing at the point of separation, making a narrowed end in which to trap the refrigeration tubing. On the right, a file is forming the bevel needed for good airflow.

Next place the tubing on a hard surface and insert the end of a small drill bit about 1/2-inch into the refrigeration tube. Tap lightly on the last 1/4-inch of the copper tubing while revolving it around the hardened shank of the drill bit. The tubing will expand under the hammering to form a misshapen flare.

Chuck the contact tip in your drill and revolve it under a file until its threaded end slips into the refrigeration tube, then sand its shoulder area near the planned joint. If you use a standard tip, reverse its position in the drill chuck and spin it under a file to taper the forward end before inserting it in the refrigeration tube. Remember to leave some material surrounding the tip's orifice (as shown in previous drawings).

Use the 3/16" round file or a nail with sandpaper wrapped around it to carefully enlarge the burr in the 1/8" pipe until the copper tube will just barely slip through it. Then clean and flux the outside of the tube, and insert it into the 1/8-inch pipe, through the threaded end as far as the tubing's flare allows. Place the two parts on a table and use another piece of 1/8-inch pipe to gently force the outer pipe down the

Fig. 3-20 The refrigeration tube and threaded section of pipe. The excess protruding past the thread of the pipe can be sanded away after brazing. At the other end, the tube protrudes beyond the filed out burr left by the pipe cutting tool.



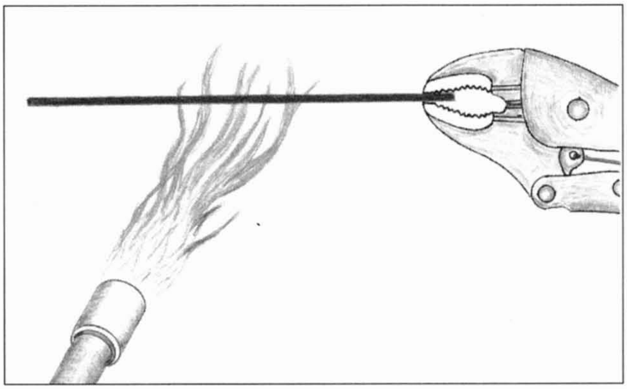
rest of the way over the flared end. If you have no extra 1/8-inch pipe long enough for this, gently place a set of pliers on the tubing over the end of the outer pipe and tap down on the pliers to force the parts together.

Thoroughly clean off any flux on the thread and wipe a little oil (any kind–even salad oil) on the threaded end. This will burn to carbon, protecting the thread from being silver-brazed. Wash and dry your hands before handling the parts.

Holding the parts trapped with one hand, insert the drill bit's shank about 3/16-inch into the flared end of the tubing leaning the bit at an angle, and moving it in a circular motion, reshaping the irregular flare. This will make a better seal for the braze.

With clean hands, flux the contact tip, keeping the flux away from its end. Push it slowly into the 1/4-inch tube with a twisting motion (as though it were a threaded part). Revolve the two parts under your finger, smearing the excess flux around the joint. Smear a little flux around the outside of the joint where the refrigeration tube extends beyond the 1/8-inch pipe.

Fig. 3-21 An oiled metal strip clamped in locking pliers being given a thin coat of carbon by the black wisps of almost pure carbon from the feeble yellow flame of a fully choked burner (running with a temporary accelerator installed). The oil on the metal surface also burns down to carbon. "Carbon blacking" a part or supporting surface will protect it from being accidentally brazed.



Read Chapter 12 "Brazing." Then place the parts on built up sections of carbon-blackened metal for brazing in the horizontal position. Or, place them on a piece of carbon-blackened metal and held with locking pliers for brazing, in the vertical position. Although the parts are a tight fit at room temperature, you need something to keep the tube from falling through the pipe bottom after the pipe expands from heating in the vertical position. Pass the torch flame back and forth over all three parts until they are a bright red, but not orange (use a reducing flame). Heat the parts from both sides, but do not move them. Once you reach red heat, begin brazing with the contact tip, then move on to the larger joint. Avoid drawing the braze to the threaded end of the 1/8" pipe.

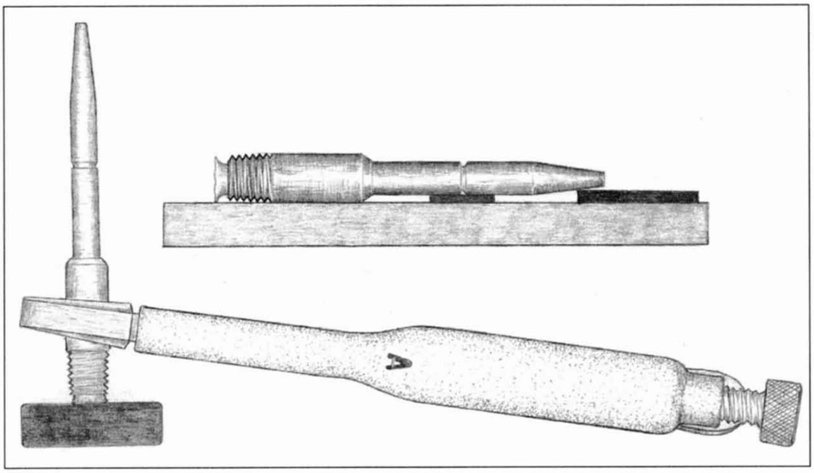


Fig. 3-22 The accelerator parts resting on carbon blackened surfaces. The illustration also shows the same parts clamped in the jaws of locking pliers and sitting atop of a carbon-blacked flat bar. Either method will protect the parts from being brazed to the supporting surface.

If you have a die, clean and chase the thread after the accelerator cools. You can lightly clamp the die in locking pliers. Gently run the torch tip cleaner into the accelerator orifice (once only). If you have a counter sink, use it to form a bevel inside the accelerator's threaded end (or use a drill bit run backwards). Be careful to stop short of the exterior thread. Now deburr the bevel where it meets the orifice with sandpaper (not the file) and clean any flux out of the accelerator's interior. Then use a pipe cleaner to remove any metal particles.

Refrigeration tubing is easily bent. There is over an inch of tubing between the contact tip and the brass pipe. This section can be gently bent in order to straighten the accelerator, after brazing. The accelerator can also be bent into position within the burner afterward.

This accelerator allows the ball valve to become part of the handle when the burner is used as a hand torch, but a little extra power can always be added to the burner by placing the 90-degree elbow after the valve allowing the valve to become part of the accelerator. One position shortens the torch, while the other gives maximum power.

The long torch tip cleaners allow you to clean the orifice from the backside of the accelerator, which is recommended if it becomes clogged from particles entering its orifice (this can happen during improper shutdowns of a forge and from oxides popping off metals when the burner is used as a torch). If the accelerator gradually becomes clogged from waxy buildup (due to fuel impurities), unscrew the accelerator and use the tip cleaner from the front side, gently tapping the accelerator's threaded end on a wooden surface.

Maintenance

Once a burner is properly tuned, it is mostly trouble free. There are four factors worth mentioning however:

First, the accelerator orifice must be cleaned out occasionally with torch tip cleaners. Because propane gas can leave tarry buildup inside of the orifice at the shoulder where the larger pipe abruptly narrows at the back of the contact tip. Also, any flux or metal filings left from the accelerator's construction will eventually collect here. If the burner's performance suddenly falls off, a partial plug in the tip's orifice is the probable cause. When using the tip cleaners, you must remember that they are essentially files and that copper is soft. Remove the accelerator from the burner to clean it. Push the proper size wire into the contact tip once and after withdrawing it, gently tap the bottom of the accelerator against a level surface to allow the obstruction to fall out of it. Do not use the tip cleaner as a file or you will degrade the orifice.

Second, the choke should be closed completely at shutdown when the burner is used in a forge. This is done in order to prevent unwanted heating from chimney effects. After shutdown, buoyancy causes the heated gasses to back up through the burner because it is no longer creating a positive force. Improper shutdowns can also promote plugging of the very small tip orifice.

Third, the burner nozzle must be protected from overheating. It should sit at least an inch inside of the refractory opening when used in a forge or furnace; to shelter it from the main heated area of the forge's interior.

Finally, if this or any of the inductor burners described in this book are run at top dead center (vertical position and facing straight down) they will run erratically and can be snuffed out. This is not a malfunction. The spent gasses rising past their air intakes will affect them adversely. Simply move them back to an angle sufficient to allow the hot gasses a clear exit path when they are used as torches. Make sure the burner collar is sealed when they are positioned at TDC in a forge.

4

Building the 3/4-inch Forge Burner

A 3/4-inch jet ejector burner is used to power the portable forge in Chapter 5. It has the same high flame temperature and fuel saving characteristics as the 1/2-inch burner, but with a greater output. A ball valve and its fittings are listed among its parts, and they will be used for testing the burner. Afterward, they can be recycled into fittings for the forge.

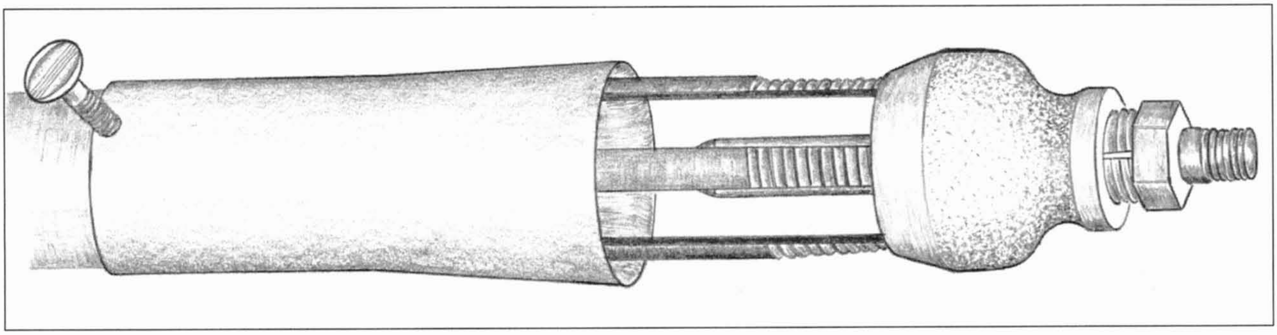


Fig. 4-1 Detail of the 3/4-inch forge burner

The major difference between the 1/2-in and the 3/4-inch burners is size and part # 4. You will be referred back to Chapter 3 instructions for many of the steps in its fabrication, since most of the drawings in Chapter 3 will be helpful in constructing this burner.

If you can find a 1/8 x 3/4 NPT bell reducer, it can be employed in a similar fashion to the hand torch's bell reducer. Since they are seldom found in stock, a more common part is shown in its place. This bell reducer employs a reducing bushing which is used as a self-tightening collet instead of the locking set screw that was previously shown. Fig. 4-1 shows the bell reducer and collet in action. You can also refer back to Fig. 3-15, parts # 4B and #19, which show this as an alternative fitting on the hand burner.

The gas accelerator assembly is made from a completely different plan from any of the three designs given for the previous burner. Each burner shown will feature a separate accelerator. Except for the MIG tip orifice sizes, all of these gas accelerators are meant to be interchangeable.

Fabrication steps #6 and #7 show the same kind of drilling technique for making the air intakes as used in Chapter 3. However, if you secure the burner tube at a comfortable height these larger openings can be made by chain drilling the air intake ends and making the two longitudinal cuts just inside of scribed lines with a cutoff wheel mounted on a 4 1/2-inch angle grinder. Using this procedure avoids the need for the larger electric hand drill and 1/2-inch drill bit called for in the special tool list; however, you must lay out and scribe the desired rectangular openings using the four equidistant line centers.

Materials List:

(1A) 1 1/4-inch ID #316 SS tube 2 1/2-inch long, ID 1.260" typical, .95" wall [1]
(1B) 1-inch sc. # 40 galvanized pipe or sc. # 20 black wall pipe, 1-inch long [2]
(2) 3/4-inch # 40 black wall pipe nipple twelve inch long
(3) 1-inch x 24-inch long galvanized steel pipe [3]
(4) 3/4 NPT x 1/4 NPT bell reducer [4]
(5) 1/4-20 thumbscrew and 1/4-inch flat washer
(6) 1/8-inch brass pipe nipple 4-inches long
(7) .030-inch and .035 MIG welding contact tips 11/2-inch long [5]
(8) 1/4 NPT gas rated ball valve [6]
(9) 1/4 x 90° street ell (or 90° elbow and a second short nipple)
(10) 1/4 NPT short nipple (preferably hex)
(11) 1/8 NPT x 1/4 NPT bell reducer (or threaded bushing and 1/4 NPT coupling)
(12) 9/16-18 LH thread to 1/4 MPT Outlet Bushing or 3/8 flared fitting [7]
(13) 1/4-27 F x 1/8 M reducing sleeve [8]
(14) 1/8 NPT brass coupling
(15) Four #8 x 32 x 1/2-inch SS set screws
(16) Four #8 x 32 X 1/4-inch SS set screws
(17) 1/8-inch X 1-inch long brass pipe nipple
(18) 1/8 NPT x 1/4 NPT steel or brass bushing
(19) One sheet of #120 sand paper
(20) Silver braze and flux

Note: Parts #14 and #17 are for the drilling and threading fixture. If you keep the fixture from the hand torch, you will already have these parts. Part #13 is used with a standard left-hand fuel nut. Use a flared fitting in its place if you have a propane hose with an appliance configuration.

Tool list:

This tool list is similar to the list in Chapter 3. The exceptions are the larger drill chuck needed and the changed drill bit sizes.

(A) 1/2-inch electrical drill [9]
(B) #29, 5/32-inch, #3, #7, 5/16-inch, 13/32-inch, "Z" size, and 1/2-inch drill bits [9]
(C) Hacksaw with fine tooth blade (unless you find a 3/4 x 1/8 bell reducer)

Fabrication:

1. Assembling the burner nozzle, parts #1a, #1b, and #16

This step is nearly identical to Chapter 3 except for the part's sizes. Two different nozzle sizes (1 1/4-inch ID and 1 5/16-inch ID) are given because SS tubing can be more difficult to obtain than pipe. The different diameters and variations in the 3/4-inch black wall pipe of the burner tube (part #2) may call for sc. #20 pipe instead of sc. #40 galvanized in order to avoid extensive grinding for fit-up. One cannot predict requirements with so many variables. Using the 1 5/16-inch ID SS tube will give slightly better performance than the 1 1/4-inch ID tube and will take very little grinding with sc. #40 black wall pipe, but you might have to increase the burner collar size on your forge if the tube wall is thick.

2. Preparing the burner body, part #2

Cut the threads off one end of a 3/4-inch pipe nipple 12-inch long, and continue through the same steps of Chapter 3.

3. The flared choke sleeve, part #3

This part is made of 1-inch galvanized pipe and is 4 inches long when finished. Otherwise all instructions from the choke section and the flaring instructions from the advanced options section of Chapter 3 apply. Unlike the hand torch, it is necessary to use the advanced options to get proper performance from this burner.

4. Preparing the 3/4-inch to 1/4-inch bell reducer, parts # 4 and #18

Use all the same procedures shown in Chapter 3, except for installing the locking set screw (part #16). This part is replaced by the 1/8 NPT x 1/4 NPT bushing (part # 18). Prepare the bushing by marking four places on the face of its threaded end for the cross cut slots (use dividers to make sure the spacing is equal). Then drill out the threaded hole with a 13/32-inch drill bit. Next, place the bushing threaded end up, in a vice, and use the hacksaw to form slots. Saw all the way down from the threaded end, to the shoulder of the hexagonal faces. Clean out internal burrs with the round file. Use a metal bristled brush to clean the exterior thread. Parts #4b and #18 are also shown in Fig. 3-15.

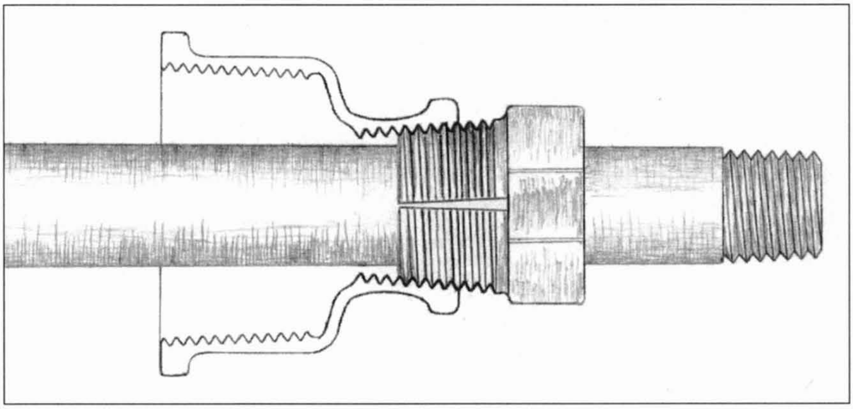


Fig. 4-2 The back portion of the accelerator tube is locked in position by the pinching affect of the bushing being used as a collet. The forward portion of the thread is clamped closed as the bushing is screwed into the small end of the bell reducer (shown in cross-section).

5. Installing the thumbscrew, part #5

The burner is set at or close to a vertical position in the forge, but the thumbscrew slot is not recommended over the threaded hole option because of the longer length of the flared choke. This keeps the choke sleeve mounted thumbscrew well away from the air intakes. To place the thumbscrew on the choke sleeve, measure 3/8-inch from the sleeve's forward edge and place a 1/4 x 20 threaded hole. Follow the directions given in Step 5 of Chapter 3 if you choose to use a slot.

6. Laying out the air openings, part #2

Lay out four equidistant longitudinal lines on the pipe, use the same methods in Step 6 of Chapter 3. These are the center lines for the air openings.

Mark a line at the lip of the bell reducer, then mark five more lines at 1/2-inch intervals, creating a total of six lines around the pipe. Use the same methods as outlined in Chapter 3 to transfer the lines around the pipe's circumference. Scribe parallel lines down the pipe from the end marks through the circular marks. Punchmark all the intersections of lines with four rows of punch marks, six marks to a row.

Since the bell reducer will cover the back half of the first hole, the air openings are 2 3/4–inch long. To use the grinding method and layout to chain drill 1/8-inch pilot holes across the forward end of the openings. The air intakes will then end up about 2 5/8–inch long which is fine. This method requires additional longitudinal lines to be laid out at 1/4-inch on either side of each center line (see Fig. 7-3).

7. Cutting the air openings

Review the directions of the same in Chapter 3. Drill a 5/32-inch pilot hole in each mark and enlarge all the holes to 1/2-inch. Use the right angle grinder to remove most of the metal left between the holes and finish smoothing the sides of the air slots with a flat file. Finish Step 7 according to the instructions in Chapter 3.

Remember to bevel front and back edges of the air intakes, the same that is shown in the advanced version of the hand torch. A forty-five degree bevel and a longer bevel area gives better performance. The forward bevels make the difference between acceptable and exceptional performance.

8. Placing the aiming screws, parts #15 & #16

The collet should allow the accelerator to line up perfectly with the burner tube's axis. If it does, no aiming screws are needed. Screw the bell reducer on the pipe's end. Now, file the end of the air slots square and even with the bell reducer's lip. Grind the bell reducer's lip flat and then bevel it (see Advanced Options section of Chapter 3). Afterward, except for the comment about deliberately aiming the accelerator out of true (which doesn't apply to any of the larger burners), follow the directions for the bell reducer in Steps 7 and 8 of Chapter 3. If you use aiming screws, tighten the collet only after they are set.

9. Making the gas accelerator assembly, parts #6, #7, #13. #14, & #17

If you use a MIG contact tip with a 1/4-28 threaded end, a fourth method of building the gas accelerator is possible. The reducing sleeve (a lamp part) has 1/4-27 inside thread. The thread is so similar to the Tweco thread that it can simply be chased with a 1/4-28 tap. The tap will follow the old thread accurately, so there isn't any worry about not having the new thread running axially true. The lamp part also has a handy shoulder to rest against the end of the 1/8-inch brass pipe nipple which helps to maintain an axially true fit.

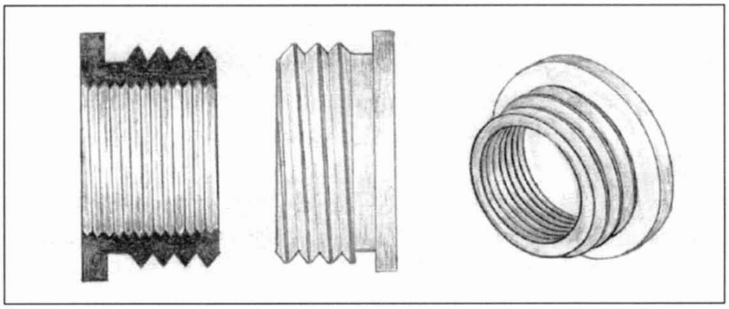


Fig. 4-3 The side view of the 1/4-27 F x 1/8 M reducer sleeve (part # 13) in the middle along with cutaway and perspective views. This is a commonly available lamp fitting.

Begin by using the drill and tapping fixture from Chapter 3 (parts #14 & #17) to make sure the pocket in the accelerator's gas tube (part #6) is drilled axially true. Use a 13/32-inch drill bit. Set up the parts, as you did then, and ream out the length of the thread plus 3/16-inch for the lamp part's pocket– a total of 9/16-inch deep. Then, remove the 1/8-inch x 4-inch long pipe nipple, cut the threaded end off and true up the cut end with a file by spinning it in the drill chuck. Check the end with a square for accuracy.

Carefully rotate the 1/4-28 tap through about one-half turn in the lamp part, making sure it isn't cross-threaded. Then, chase the thread (do not use tapping fluid). Use the same care as if you were making a new thread instead of just chasing an old one. Once you have accurately begun the new thread, it is best to hold the part lightly gripped in pliers to finish chasing. Use the pliers on the exterior thread, which will be filed off, rather than by the part's lip.

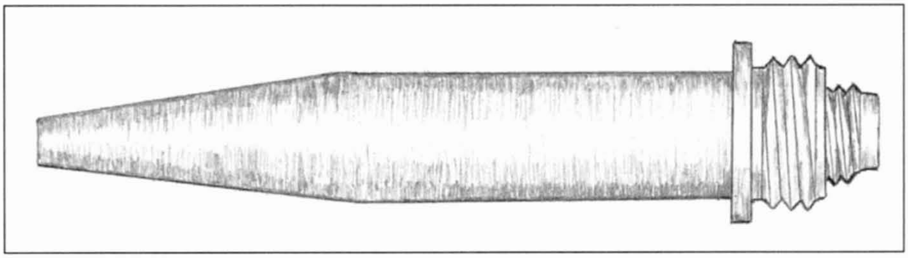


Fig. 4-4 The threaded reducer (part #13) is screwed onto the MIG tip (part # 7) and ready to be held in the drill chuck. The MIG tip extending beyond the end of the reducer, if left on, would seriously hamper acceleration of the gas molecules.

After chasing the thread into the lamp part, blow any metal shavings out of the new thread and screw the part onto the MIG tip (part #7) with its lip facing forward. You will notice that the MIG tip's thread is about 5/32-inch longer than the lamp part. If left, this excess would protrude into the gas tube, seriously interfering with laminar flow, just as the coupling in Chapter 3's temporary accelerator did (but to a lesser extent). Chuck the parts in your drill motor, clamp a small drill bit in the locking pliers, and drill away the protruding area. You should end up with the copper tip's threaded end being even with the brass thread of the lamp part and a new taper leading into the copper orifice. Use the torch tip cleaners to clean any burr from the orifice and blow out any metal filings.

Next, spin the parts under a file to remove the outside thread and reduce the lamp part's diameter until it will fit within the reamed out pocket of the gas tube (part #6). Also, remember to keep the file flat against the face of the spinning part so that the part's outer face remains parallel with the inside thread. Check the two parts for fit frequently as you do this. When the lamp part fits into the gas tube's pocket, unscrew the copper tip. Reverse the tip in the drill chuck and run the front under a file to taper the tip if you had to buy a standard tip.

Flux the outside of the lamp part, being careful to keep the flux away from the thread end of the part. Place the lamp part into the upturned hole of the1/8-inch pipe nipple and make sure that the lamp part's shoulder is contacting the pipe edge all the way around its circumference. Silver braze the parts. The 1/4-inch x 1/8-inch bell reducer makes a handy temporary base in which to place the gas pipe and other accelerator parts for silver brazing in a vertical position (clamp in locking pliers). Unscrew the contact tip and clean the excess flux inside and out from the accelerator (review Chapter 3, Accelerator Section). After brazing, the pipe is chucked in the drill, and spun under the file to remove any excess solder from the exterior of the pipe and to bevel the gas pipe's forward end.

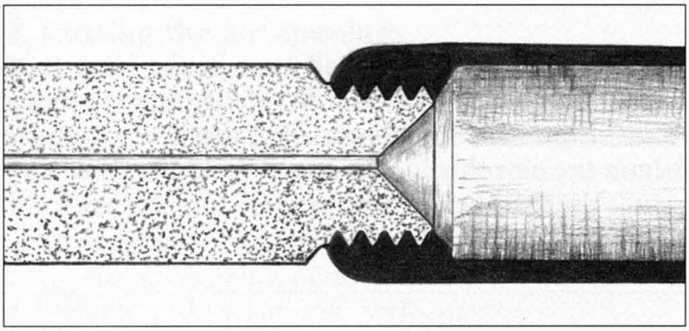


Fig. 4-5 The joint made by the altered MIG contact tip and the silver soldered lamp part. The darker area on the right is what remains of this part and the forward portion of the gas tube made from the 1/8-inch pipe nipple. Note its beveled shoulder and the radius formed by the silver solder on the inside of the tube.

After removing the pipe from the drill, use a round file to clean out the flux. Blow any metal shavings out of the accelerator assembly. Use the tap to chase the thread, and use Teflon tape to ensure a good seal, keeping the tape away from the thread's end. Then screw the contact tip into the gas pipe.

10. Assembling the valve and hose fittings, parts #8, #10, #11, & #12

Screw the 1/8 NPT x 1/4 NPT bell reducer on the accelerator. Screw the 1/4-inch short nipple into the bell reducer and the ball valve on the nipple. Screw the 9/16-18 LH thread to 1/4 MPT outlet bushing (or a 3/8 flared fitting) into the back of the valve. Use gas rated Teflon tape or sealant and make sure to keep it away from the last two threads on the parts. Your burner is now ready to tested.

11. Testing and tuning

The amount of overhang on the nozzle is between 1 1/8-inch and 1 1/4-inch. The accelerator is kept axially true and 1/4-inch back of the bevels at the front of the air openings. Temporarily remove the thumbscrew and slide the choke all the way forward to clear the intake area, then place and lock the accelerator in position. This puts the accelerator forward of the choke sleeve's flared section, even when it's in the full open position. Minimum starting pressure on this burner is about 6 PSI. Otherwise, it will tune and test the same as the advanced version of the hand torch. Once the burner is placed within a forge, the flame will lengthen and change shape. This burner uses both .030-inch & .035-inch MIG tips for best performance in all pressure ranges.

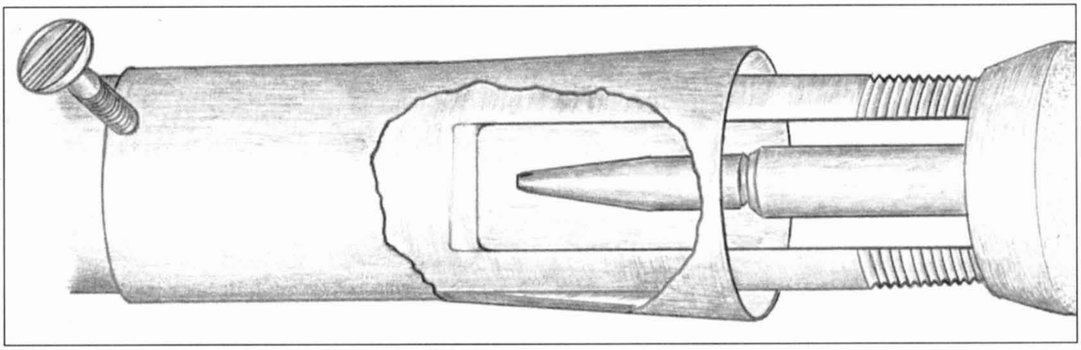


Fig. 4-7 A cutaway within the flared portion of the choke sleeve allows the MIG tip to be seen in position, 1/4-inch away from the beveled outer edge of the air intake. The bevel, which is hidden from this angle is shown as an x-ray view. Note how the narrow end of the choke sleeve is even with the air intake's beveled forward edge. This position directs maximum airflow toward the bevel, which in turn redirects the air into the mixing tube with minimal drag. This is the best setting for the accelerator and choke through most of it's pressure range.

12. Maintenance

General maintenance procedures for all the burners in this book are given in the Maintenance section of Chapter 3. Only additional maintenance considerations will be given the following chapters.

Tips for group projects

The forge in the next chapter was designed especially for this burner and tube forges are particularly advantageous to build as group projects. When a number of forges are being made, the ceramic lining can be purchased by the roll (at a discount). Also, because the fiberboard enclosures are roughly "C" shaped, cardboard templates can be made which allow better use of the board. This reduces waste in cutting parts from this expensive material. Bonding mortar is inexpensive, but buying the ITC # 100 in larger containers will create significant savings. When purchasing the larger amounts of ceramic products, remember to ask for the same discounts an industrial customer would receive.

Likewise, running a production line when building the forge shells can significantly reduce the workload. Setting up a number of burner collar openings at one time makes using a drill press worthwhile. This promotes safety and tool life—especially when using a hole saw.

Groups can also accumulate special needs. It is almost inevitable that one or more people will end up behind in their work. They will need to shave time off their project schedule in order to finish with the rest of the crew.

As an example, one time consuming task is drying out the interior of the forge. To speed up the process, hold the burner at about eighteen inches from the shell while passing it over the steel surface will quickly heat the damp interior. The constant movement and distance preserves the heat resistant paint. As soon as water vapor starts escaping, shut down the burner, and wait about five minutes. When the vapor stops escaping, run the burner pointed straight into the forge from about six inches away for a few seconds, then turn the forge and repeat the process from the other side. Next, reheat the outside of the forge while watching for vapor and shut down when it starts escaping again. Then repeat the interior heating. Watch closely and stop if the interior coating begins cracking or glowing. Done carefully, this technique will safely reduce the drying process to an hour, allowing the builder to go straight to the forge heat curing sequence. Because there is some risk of damaging the interior coating, this method should only be used when someone is seriously behind, rather than as standard practice.

An alternate method is to put a light bulb on bottom end of the forge tilted up allowing the warm air to rise past the damp insulation; then reverse the ends.

5

A Propane Bottle Gas Fired Forge

This forge is fabricated from a twenty-pound/five-gallon propane cylinder and fired with the 3/4-inch jet ejector burner. A number of building methods are shown allowing the forge to be welded, brazed, or bolted together. You may start off with just the basic forge and later add other options and equipment such as: two different idler valve systems for fuel economy, a separate hand burner with a fuel hose, and the forge cart in Chapter 6. Building this equipment is a reasonably easy task requiring the use of some hand tools. But first, let's look at the design principles of gas forges.

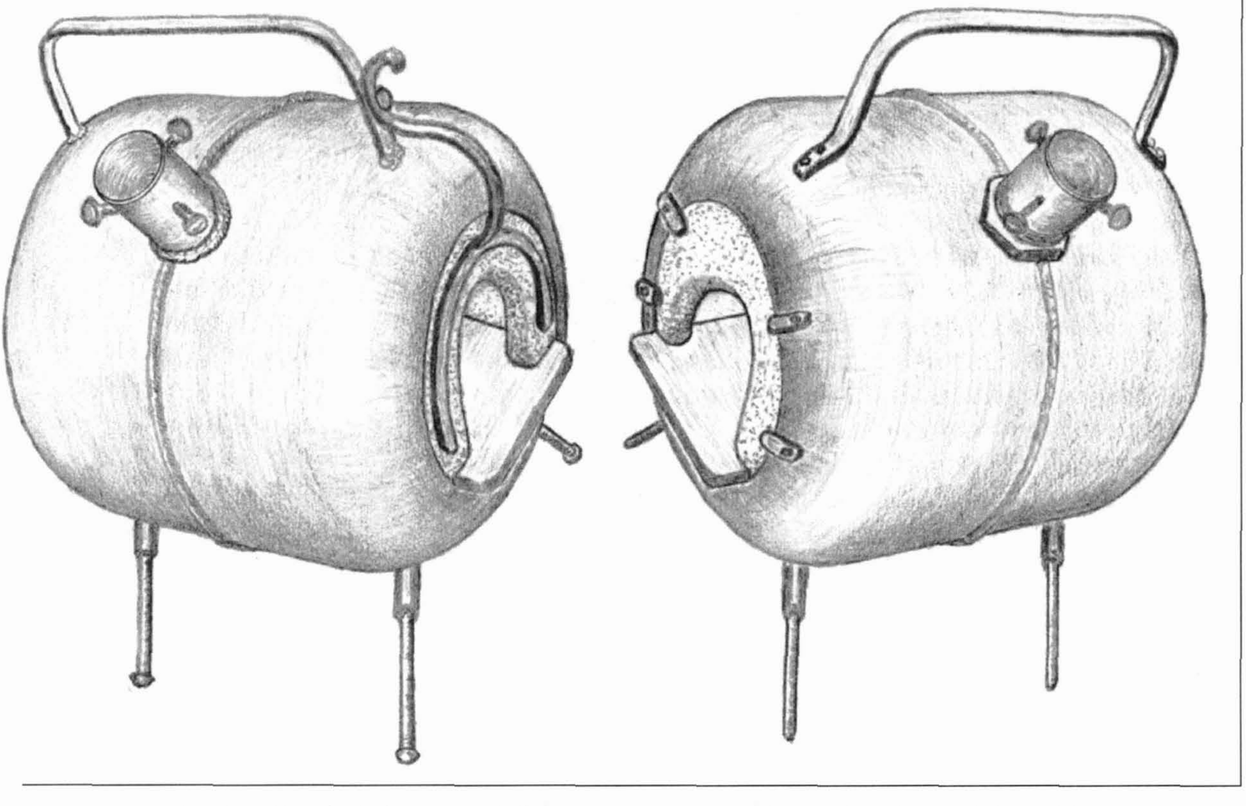


Fig. 5-1 On the left is a welded forge. Its door is held closed with a "u" shaped bar attached to the handle with a thumbscrew. On the right is a fastener assembled forge. Its door is trapped in place with four curved flat bars screwed to the shell. Handles are 4-inches high.

Forge design

The primary purpose of a forge is to provide an enclosed environment in which to heat the work with minimal energy loss. It must also shield the work from oxidation as much as possible in order to reduce scale formation. With these goals in mind, the design of the forge logically begins with its exterior.

It is a common error to build the forge shell from heavy gage material. Only enough thickness is needed to provide support and rigidity to the forge. Some kilns, for example, use expanded metal for a shell. But, this is probably going too far in a shop environment, where the forge needs some protection from impacts. On the other hand, it is a common mistake of building forges from1/4-inch to 3/8-inch steel where 1/16-inch to 1/8-inch wall thickness is a sensible working range.

The next consideration is size. If the forge's internal area is too large for the burner's BTU output, you can't reach welding temperature. While there are well- known cubic area formulas, they are outdated for use with these burners. It is of equal importance to avoid making the forge diameter too small. This will cause the insulating layer of ceramic fiber to overheat and be destroyed.

When making a tube forge with a six-inch interior diameter, use nothing larger than the 1/2-inch burner. The 3/4-inch burners can be used with an interior diameter of nine-inches. 1-inch burners can be used with a twelve-inch internal diameter. The 1 1/4-inch burner should not be used with a fiber lining. A ceramic shell or firebrick is suggested, as you would otherwise need an interior diameter of fourteen inches to preserve the ceramic fiber. You can figure the most effective width of the heating zone to be about the same as the diameter recommendations. These burners can be turned up enough to heat much larger areas, but then the exchange of atmospheres within the forge is too rapid for economy.

You must keep the burners aimed toward the center of the high alumina kiln shelf, from a steep angle (a minimum of 80 degrees is best), in order to spare the lining from direct heating by the flame. You will still get a swirling action to the hot gasses. "Top Dead Center" can even be used if the burner opening is sealed. This position is preferred by many and will give maximum protection to the lining. The burner collars (holding devices for the burners) must be able to seal the burner opening against the introduction of secondary air.

The body of even a well-insulated tube forge must be held at least four-inches away from the surface it rests upon for safety and to keep heat build-up from distorting the shell. Legs to hold the shell up should spread out widely for stability. One or both ends of the forge should open for access.

Interior materials

The shell provides support for the burner and controls. It contains the lightweight insulation, and the "furniture" that does the actual work of controlling heat dissipation. The insulation is ceramic fiber.

Durablanket and Kaowool are the two well known of brand names for ceramic fiber products. Ceramic fiber is available in many forms. The two forms used in the forge are ceramic blanket (linings) and ceramic board (end pieces or closures). The blanket comes in two common densities, #6 & #8, for six and eight pounds per cubic foot.

The blanket used for gas forge lining should be of eight-pound density. #6 cannot be used without Rigidizer. The thickness of the forge lining should be a minimum of two inches; three inches is even better. This should be accomplished with multiple layers. Single layers will tend to crease as they are bent around the shell, creating ridges. The minimum temperature rating of the outer layers should be 2300°F to 2400°F. The inner layer (which is directly exposed to the flame) should be rated for 2600°to 2700°F. These ratings are for continuous duty. When ceramic fiber products are subjected to temperatures above their design specifications for very long, they tend to degrade. The most important change is shrinkage—as much as twenty-five percent loss of volume with severe abuse.

The application of a layer of ITC # 100 seals the fiber and reflects much of the forge's heat away from it, increasing the service life of these products fuel efficiency. This layer also acts as a sealant against particulate drift. Continually overheating the forge results in spalling of this layer as the fiber shrinks behind it causing chunks of the rigid coating to separate. The use of Rigidizer (a colloidal silica mixture) previous to application of the finish coating may reduce the problem.

The ceramic board is made of the same high alumina and or zirconia fibers as the blanket. The difference is that ceramic board is compressed into a more solid form, which can hold a physical shape. It is much denser than the blanket lining. Ceramic board can also be purchased as blocks, but these products are quite expensive.

Kiln shelving

Furniture is the term for shelving and other devices used to support and separate glass or pottery articles in ceramic kilns. Kiln shelving is used for the same purpose in the gas forge. Small parts are usually allowed to rest directly on the forge shelf. It helps protect the more heat sensitive fiber products by taking the direct blast of the gas flame. It is also the main barrier protecting the ceramic fiber from the chemical attack of superheated fluxes during forge welding operations. Otherwise the hot flux would fall right through them, leaving voids. It will sustain temperatures to 3100° F and has some physical strength. Kiln shelving is mostly made from high purity alumina, but unlike the fiber products it is very dense. Ceramic "posts" are used to help support multiple pieces or long shelves in larger forges. Ceramic tile is made of the same high alumina as shelving and posts. It is available in a variety of widths. If you plan to do a lot of forge welding, ceramic tile can be a good way to lengthen the life of your shelf.

The multiple burner forge

When using multiple burners, do not space them closer together than the diameter of the forge chamber. Leave them only one-half that diameter from the openings for ideal heating. Multiple burners need a master valve for the entire system. This should include an idler control and pressure gauge. There should also be small slave valves for each of the individual burners so that they can be turned off while the rest of the system is running. The manifold and piping for such a system is shown at the end of this chapter.

Burners that are not in use must have their chokes closed. If they still overheat, stuff a ball of ceramic fiber into their nozzles (don't forget the stuffing is there when you decide to light the burner later).

The burner collar on a forge should be designed so as to allow the burner to be aimed to some extent.

Long forges with multiple burners should have a movable interior baffle so that the area of the forge not in use can be isolated. This allows the size of the heated section to change. Shaped firebrick makes a good partial obstruction to airflow in smaller diameter forges (use the heavy facing brick). In large diameter forges, a piece of high alumina kiln shelf material can be shaped and laid on the forward side of an SS angle frame, which is tilted back. The baffle must leave sufficient space around it so as not to cause back pressure. The amount of clearance is a matter of trial and error, because how much is needed will be dependent on how high you run your burners.

Start off with 3/4-inch of clearance. If the exit flames of the forge are still blue after the forge is completely warmed up, the baffle is restricting exhaust and has to be reduced in size. Baffles should be coated on their forward side with ITC #100. You might decide to build more than one baffle for different purposes.

Multiple burners can overcome the exhaust capacity of the forge openings. If you find your burners aren't operating properly when all of them are in use, this is almost certainly the problem, and you must retrofit additional exhaust openings. Place the auxiliary exits on the far side of the forge from the burners and facing as near to the horizontal as the kiln shelf allows. This is necessary in order to keep the spent gas well clear of air intakes on the burners. Retrofitting is easier than it might at first seem to be, because the insulation isn't much bothered by hot work on the shell.

The propane bottle forge

This forge was inspired by the smaller Ron Reil Mini-forge, which is featured on his web site. The propane bottle forge is larger and more elaborate than the Mini-forge, and it will become a general workhorse in many shops, while remaining portable. It will also lay the groundwork for your own design.

Materials list

(1) A new five-gallon propane bottle, a used bottle second choice
(2) A 1 1/2-inch ID pipe 3-inch long [1]
(3) One large steel flat washer, with a 1 1/16-inch hole, and at least 1 1/2-inch outside diameter
(4) Three 1/4 x 20 thumbscrews 1-inch long and one 1/2-inch long
(5) 3 1/2 linear feet (42 inches) of one-inch thick, 8 lb ceramic fiber blanket (rated for 2300°F) from a 24-inch wide roll [2]
(6) Two square feet of one-inch thick ceramic fiberboard (rated for 2300°F)
(7) One mulite or high alumina kiln shelf, six inches wide by sixteen inches long. It must be at least 1/2-inch thick, but not more than 3/4-inch.

(8) One spray can of heat resistant paint
(9) One pint of ITC # 100 infrared reflective coating
(10) One pint Bonding Mortar [3]
(11) 3/4-inch jet ejector burner [4]
(12) Fuel gas regulator with gauge, propane hose, (quick disconnect is recommended), ball valve, and a fully charged propane bottle for use with burner [5]
(13) One pair of long sleeved rubber dishwashing gloves, an approved respirator
(14) 1/8-inch x 1/2-inch steel flat bar 5-foot long [6]
(15) 1-inch pipe plug
(16) Welding rod or brazing rod, flux, and a small brass cleaning brush [7]
(17) Four 3/8-inch carriage bolts and coupling nuts [8]
(18) Four 3/8 x 1-inch bolts and locking washers (completely threaded, no shank)
(19) Quart of colloidal silica rigidizer (recommended)

Tool list

(A) Electric hand drill, along with three 1/8-inch drill bits, a 5/16-inch bit, a # 7 bit, a 1 7/8-inch hole saw (optional) [9]
(B) 1/2-inch right angle grinder, with thin cutting discs and a medium grit flap-disc. A diamond-cutting disk is optional (see Resources)
(C) Saber saw and steel cutting blades [10]
(D) Welding machine helpful [11]
(E) 1/4 x 20 starting tap, tap handle, and tapping fluid
(F) 6-foot tape measure, 12-inch dividers, 12-inch combination square, and ink marker.
(G) Locking pliers (Vise-Grip)
(H) Two disposable 1-inch paint brushes
(I) Small center punch or prick punch
(J) Safety glasses

Fabrication:

1. Acquiring the forge shell

Building this forge begins with the procurement of a five-gallon (20 pound capacity) propane tank. It is best, when possible, to purchase an unused tank. This should end all worries about injuries from fire or explosion while working on a used tank. If you choose the used tank, don't do any burning welding or grinding on it (where sparks can reach the interior) until after it has been prepared for hot work.

Remember that when the salesperson tells you the tank is unused, there is no guarantee that he knows what he's talking about. The tank could have been used and then returned. Use the same precautions with a new tank as an old one until you know it has never been used.

Before working on a propane tank, you must make sure it is empty. If the tank is heavy it probably isn't empty. If it sloshes when moved it certainly isn't empty. In this event you must use up its contents before proceeding. Should you think the tank is empty, use the regulator's pressure gauge to check for positive pressure. If you get no reading, remove the regulator, after closing the cylinder valve. Open the valve again, with the tank outside and well away from all possible ignition sources or anything that could be endangered if the tank were to catch fire. On the side of the valve stem you will see a small inset screw. Turn the screw counter-clockwise until the bleeder valve is also completely open (some valves contain a back check assembly, which prevents gas flow from the filler orifice until a proper connection is made with an inlet adapter). The tank will retain a propane atmosphere for days, even with both valves open. With the positive pressure gone and the propane completely escaped, there will still be out-gassing from the metal interior and from the petroleum distillates on the tank bottom. Do not blow the tank out with compressed air. That would provide it with an air/fuel mix ready to ignite on the slightest spark. Instead, depress the back-check ring and fill the tank with water.

2. Removing the protective carry-collar

To prepare a new or used tank, begin by closing the valve and grinding off its collar. An inexpensive imported grinder is fine for this and can be easily purchased from a number of suppliers (see Resources). After weakening the welds with the grinder, use a hammer to break off the collar. This leaves partially ground welds to be removed.

Replace the grinder disc with a flap disc (a modern form of sanding disc) and remove the weld scars immediately. With reasonable care, the flap disc will allow you to leave the surface as smooth as if it had never been touched at all. Use safety glasses, or preferably, glasses and a face shield when grinding. If you have no shield, use your welding helmet.

3. Removing the cylinder valve

The next step is to unscrew the filler valve (called the cylinder valve). Whether the tank is new or used the valve will be very difficult to move through its first quarter-turn. Remember to turn the valve counter-clockwise. Set the tank on its side and while sitting on it, place a pipe wrench on the flats of the valve stem. Tap on the handle of the wrench with a hammer while pushing on the wrench (keep your other hand well away from the target area). A hammer blow delivered this way is equivalent to one and a half tons of force.

In the absence of a pipe wrench, place a small pipe inside of the valve opening, and beat on that. If this fails saw the stem off (it's only brass after all).

4. Laying out and cutting the first opening

If you have water in the tank, drain it out to lighten the tank while you do your layout work. Now, you must begin laying out the first opening (see Fig. 3). If you succeeded in unscrewing the valve stem, replace it with the 1-inch pipe plug. Scribe crossing lines on the square top of the plug from corner to corner, forming an "X" pattern; center punch the intersection of the two lines.

Next, set your dividers at approximately 4 3/4-inches, and place one divider leg in the punch mark. Hold the dividers vertical with one hand and guide the point of the

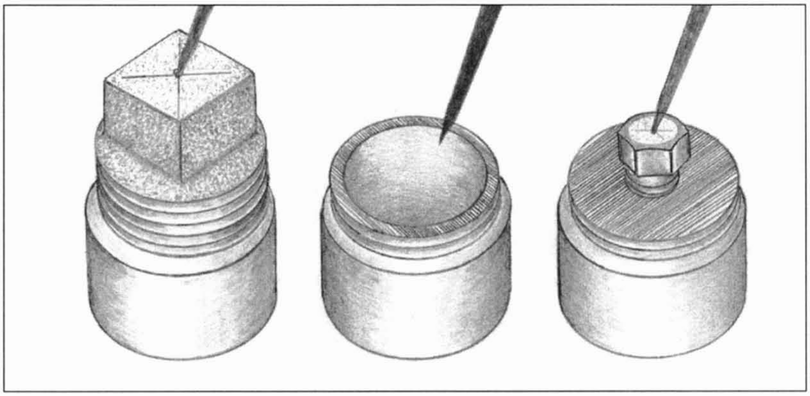


Fig. 5-2 On the left a divider leg rests in the center punched pipe plug. In the middle the leg is riding along the inside of the threaded section of a cutoff thin walled cylinder valve. On the right, the leg is resting in a center punched hex-head bolt that has been run into the thick center of a cut off valve. Valve necks can be thick or thin walled.

other leg to scribe an 8-inch circle on the tank's end. Mark and then measure at two opposite points before scribing the circle to see that it will come out to eight inches. If you end up with a circle that is not 8-inch, adjust the circle diameter on the tank's other opening to match sizes.

If you were forced to cut the valve stem off, remove the burrs from the inside of the hole in the remaining stem. There are two different wall thicknesses common to these valve stems. One thickness is about the same as pipe. For this kind, set the dividers at about 3 3/4-inch and move one leg's end around the inside rim of the hole. Guide the other leg of the dividers around the tank's surface with your other hand to scribe an eight-inch circle (remember to check the diameter before scribing the circle). The same method can be used with the heavier stem, but it is better to run a short bolt into the hole, center punch it, and proceed the same as with a plug. If the cut stem isn't completely round and has an interfering dimple, the affected portion on the circle can become the flat area described next.

Then, measure the kiln shelf (approximately 6 inches) and set your dividers to that measurement. Place both divider points on the circle and mark the places where they intersect the circular line. Then center punch these points. Place the tank on a table or other flat surface and measure each punch mark while adjusting their respective heights by rolling the tank back and forth until they are equal. Prop the tank in that position with angle irons or wood blocks.

Use wood or any other square objects to create a steady rest that is not quite even with these points (half the width of your marker below level). Use the steady rest to mark a straight line between the two points on the curved surface of the tank end. A long scribe or a new pencil will be able to hold the mark parallel. Your high alumina kiln shelf will eventually rest on this flat surface. You can use the center punch, or go over the scribed line with an ink marker to make it easier to see when cutting out the forge opening.

Make a mark in each corner where the flat meets the circle. Measure 1/4-inch up from the flat and 1/4-inch in from the circle and center punch.

Now, void the tank by filling it up to two-inches below the length of the saw blade with water, you leave very little air space to allow combustion within the tank, and you cover any petroleum distillates (tar) on the bottom of the tank. The water's

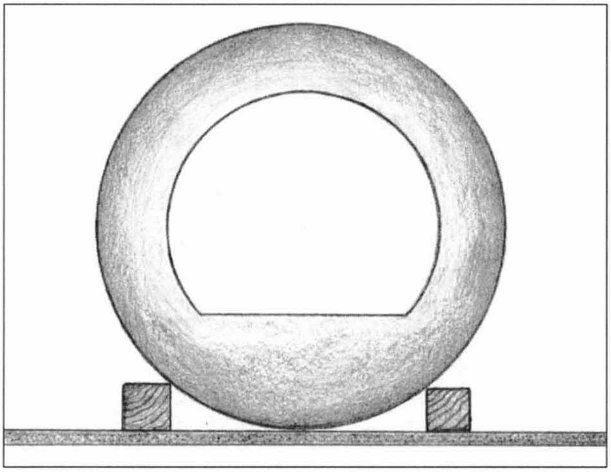


Fig. 5-3 The cut out end of the tank sitting parallel on a supporting surface. It is trapped in this position with two pieces of wood. Comparing measurements at both ends of the opening (from the opening's bottom to the flat surface) makes obtaining a parallel line easy.

weight also helps to stabilize the tank.

Use your tape measure for a "dip stick", and make sure the tank isn't overfilled. You wouldn't want to trade the chance of a fire hazard for the possibility of an electrical hazard. It is also a good idea to use a properly grounded tool on a ground fault interrupted circuit. Carefully dry the tape measure before rewinding it. Propane is soluble in water, and since propane vaporizes rapidly, it won't contaminate soil or groundwater. Propane in the tank atmosphere is only one possible fuel source. Many propane supplies contain petroleum wax (paraffin). Over the years it can build up in the container and help to capture a witch's brew of volatile products forming a sticky sludge on the tank bottom. This, rather than the out-gassing from what was absorbed into the steel, is the major source of combustibles in the tank (even without one atmosphere of propane gas). Opening the tank to the air has only a minor effect on the problem.

Drill a pilot hole in each of the two punch marks and then enlarge them to 1/2-inch holes. This will allow the saw to start cutting well inside the marked out lines. Cut from the holes toward the center of the bottom flat and toward the center of the circular line. You now have a large opening for access to the interior of the tank. Clean any tarry buildup from the tank's bottom. Be careful not to cut yourself on the opening's raged edges (you can dull the sharp edges with a file, but don't use the grinder in a dry tank yet). Afterward, grind the opening smooth, making sure to keep its flat area straight.

This same job can be quickly (but not as safely) done with a thin grinding disk or a cutoff wheel. In order to grind through the thin metal of the tank shell hold the grinder at a right angle to it and grind through the straight lines using the techniques described in Chapter 1. Do not press down on the grinder at any time—just use the grinder's own weight to do the work. The curved lines are ground through by holding the wheel at an angle and grinding a trench just inside of the line, all the way from one end of the line to the other. Then the trench is deepened gradually all around the line. As the trench deepens the wheel angle is increased. When you begin to break through the tank wall, the metal becomes paper-thin. This thin layer isn't capable of

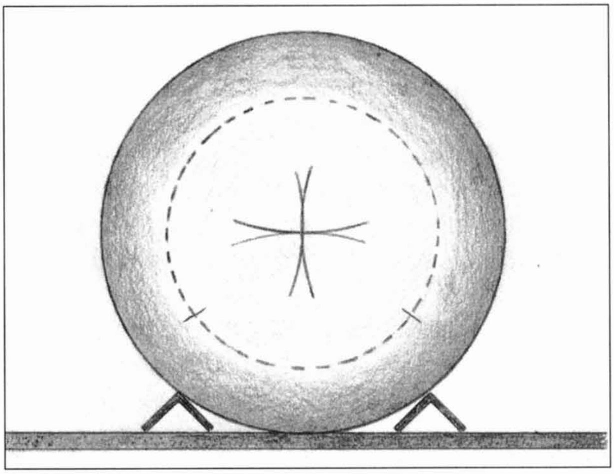


Fig. 5-4 The other end of the tank is still sitting parallel on a supporting surface. It is shown trapped with two pieces of angle iron. Transfer the measurement from the cut out end to two places on the circle as shown by measuring up from the flat supporting surface.

carrying away the grinder's heat and so it turns blue, giving you a visual clue that you need to move on to the next area. Gradually removing the whole thickness instead of grinding completely through the work in each area makes your wheel far less likely to bind. Remember the wall thickness is less than 1/16-inch. Making an opening this way only takes about fifteen minutes, even with close attention to safety. Voiding the tank is even more necessary when grinding.[12]

5. Laying out and cutting the second opening

Place the tank on the cutout opening and push clutter under its curved face to help secure it. The bottom of the tank now showing has an eight-inch foot ring of sheet metal. First, scribe a few places on the outside of the ring then remove it (as you did with the valve collar). The foot rings have welds to obstruct you from simply scribing a line around the exterior, so you are going to use the first scribed marks to find the center of this end.

Set the dividers at 4 inches and place one tip on any of the marks. While holding the dividers vertical, use the other point to scribe a wide arc within the targeted area. Move the dividers to at least two other widely spaced scribe marks and repeat the process. This will form a small square or triangle in the center of the circle; place the punch in the center of this area and mark the spot. Avoid using areas on the ring that are out of round.

Remove the ring and clean the weld scars and old paint from the area where you are going to lay out the opening. Now use the dividers to scribe a true circle.

Again position the tank on its side upon a table with the bottom flat parallel to it. Trap the tank in this position, and transfer the measurement from the finished opening to the tank's other end. Punch mark the two places on the other circle. Mark the line between them, as before. Lay out the two drill holes, and cut out the second opening. Both openings should now be centered, at the same height, and parallel with each other.

6. Cooking a used tank

Place the used tank on its end. Put three to five pounds of self-lighting charcoal briquettes inside the tank and ignite them. The fire will smolder for several hours, and clean the propane traces out of the tank's interior while cooking the paint and rust on the shell into little more than a powdery residue. After the tank cools remove it, empty the ashes, and sand the exterior for painting, using the flap disc.

A new tank can be sanded without cooking.

7. Finishing the forge shell openings

After sanding the second opening smooth, place the kiln shelf on the forge shell's flats. If the kiln shelf rocks on the supporting edges, turn it over. If the shelf still doesn't sit perfectly flat, grind or file the end openings until it does. Mark its top face to avoid confusion when you install it later.

With the forge shell still trapped in this horizontal position, estimate where the top is by eye and mark the top of the shell on the central weld seam. Measure anywhere up to five inches down the seam, to center punch a place for the burner collar hole. If you decide to place the burner at Top Dead Center (TDC at the top of the shell facing straight down) then lay the hole out there. As long as the burner collar is properly sealed, your burner will run just fine at TDC. Most people prefer the greater swirl that the angled position gives, but TDC will keep the flame more directly on the high-alumina ceramic kiln shelf. This is going to help protect the more delicate ceramic wool lining. It's a question of personal preference. Three inches down from TDC to the center of the burner collar opening is the most popular position.

Drill the burner collar opening out with a hole-saw after removing the kiln shelf and placing the forge shell on the floor with the center punch mark facing straight up. Use the angles or boards to keep it from shifting. Hole saws have a much wider diameter than drill bits, which means that their teeth will be traveling at higher speeds than they were designed for when used in the average drill. Using wax instead of oil and employing a slight orbital motion by tilting the drill around in a small circle will help extend the life of the hole saw. Cease the orbital motion when the saw starts to break through. Using a large slow drill motor in order to get the lower speed that the saw is designed for will save wearing out the saw teeth and reduce your work, but doing so increases the danger of experiencing a "merry-go-round."

The only way around this choice is to "chain drill" 1/8-inch pilot holes around the 2-inch circle and then gently rock the bit back and forth to collapse the holes into each other. This is a slow but inexpensive and safe method. It also has the advantage that the holes can be laid out in an undersized pattern and then filed out with a half-round file to a very close fit. Afterward, the opening can be filed into an oval shape while the burner and collar are aimed at the target area of the kiln shelf (see Step 9). The close tolerance fit this method achieves allows silver brazing the parts together which is a much easier construction method than hard brazing, because of the lack of brazing rod choices that most people will encounter.

8. Mounting the legs

Place the forge shell back on the table. Raise the forge shell up about 1/2-inch off the table, place wood underneath it, and check to make sure it is still level. Trap the shell with the angles or wood blocks. Place a coupling nut on both sides of one end of the shell. Position them near the end but still on the cylindrical area. They will be trapped between the tabletop and the forge body with their tops leaning inward. Weld them to the shell, or mark their outlines, drill the shell, and screw them onto short bolts and locking washers placed inside the shell.

Repeat this process on the other end of the forge with the carriage bolts. Later on the carriage bolts can be replaced with something that suits your needs.

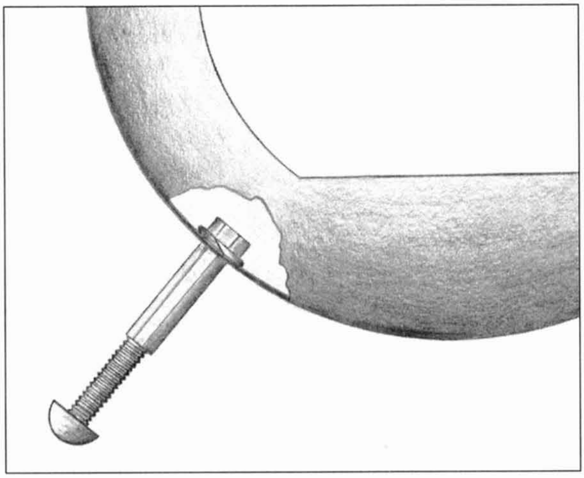


Fig. 5-5 Part of the end of the forge showing how the leg is positioned. Where the legs are placed depends on the length of the coupling nuts. The main point is to try to keep the nut at right angles to the forge shell. There is a cutaway area drawn in the shell, exposing the head of a short bolt (see fastener assembled version further on). A perspective view of the leg positioning can be seen in Fig. 5-1.

9. Layout and installation of the burner collar

On the 1 1/2-inch ID pipe measure 1 1/4-inch from one edge. Wrap a piece of paper around the pipe at this point and mark a line to indicate the circumference. Find three equally spaced places around the circumference on the line by measuring or folding the paper. Center punch and drill three holes with a #3 drill bit. Tap the holes for 1/4 x 20 thumbscrews.

The thumbscrews are not in the exact center of the pipe. The longer portion of the pipe is placed through the shell opening, which is why it has an extra 1/2-inch of length (see Chapter 5, Note 2). The pipe's short end will face outward, and should have a reasonably square and smooth surface for the flat washer to rest against later. Tack the burner collar onto the forge shell using a 3/4-inch pipe or the burner to center its aim. The thumbscrews will hold the 3/4-inch pipe (or burner) in place with its end resting against the kiln shelf center. This in turn will help to prop up the burner collar against sliding out of position while tack welding or brazing the collar to the shell (a fastener assembled version of the burner collar is shown later).

If you don't have the use of a welding machine, hard braze, or silver braze the

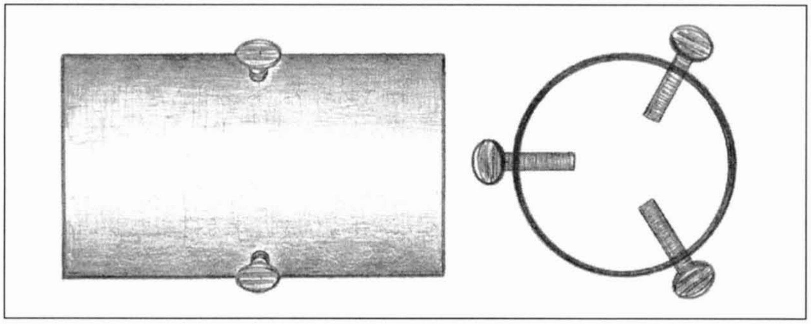


Fig. 5-6 End and side view of the burner collar with its three thumbscrews. There is no need to file away the inside burr as is done with the burners.

parts together using a regular torch set or the forge burner. This burner is perfectly capable of silver brazing or hard brazing.[13] For hard brazing with the burner, you need to employ backing insulation. Use one of the inside cutouts left over from making the end enclosure or door. It can be "cookie cut" to fit over the protruding pipe and propped against the shell (see Step 13).

When silver brazing the collar to the shell, your most likely problem will come from the failure to remove carbon from the shell's interior. Grind the area next to the opening clean and grind away the inner flap of the shell seam for about 1/2-inch on either side of the opening. The seam is bound to harbor contaminants.

Afterward clean up the forge shell and spray the exterior with the heat resistant paint. After insulating it you will be using the partially completed forge to help make the rest of the forge parts.

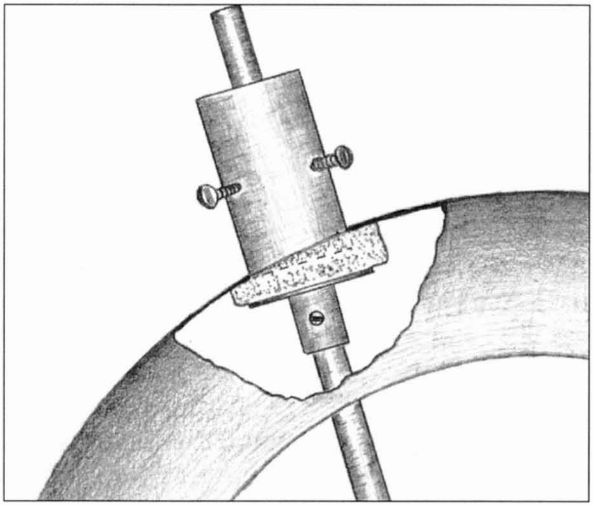


Fig. 5-7 A section of the forge looking toward one of the exhaust openings. This section shows the typical preparation for brazing a burner collar to the forge shell. You can just see the hidden line where the 1 1/2–inch pipe is surrounded by the rigidized ceramic fiber board. This backing is in turn supported by a flat washer. The washer is trapped in place by a cut section of pipe, which has been drilled and threaded for a pressure screw or by a wood sliver used as a shim. This works to keep the parts accurately positioned for brazing. The center pipe rests on the middle of the kiln shelf. Additional fiber can be stuffed between the pipe and collar to help insure that the two parts stay parallel. The thumbscrews keep the collar from sliding down the pipe, and the shell traps the whole assembly in position.

10. Insulating the forge

Use the same protections you would for fiberglass when working with these refractory products. Wear rubber gloves, a long sleeve shirt, and respiratory protection (see Resources list). Divide the 24 x 42-inch piece of blanket into two unequal parts, one 11 x 42 and the other 13 x 42. Cut the 11 inch wide piece of blanket 35-inch long. It is then rolled into a tight cylinder, and placed into the forge with the end of the wrap at the bottom. Once inside the shell, the ceramic fiber blanket will start to expand and unwind.

Starting at the bottom, push the blanket tight against the inside of the shell while carefully moving up and around the whole 360 degrees of surface. Trim away any excess material at the bottom, only if it cannot be forced back enough to let the two ends of the refractory blanket butt against one another. This is a compression fit. At first the ends will be forced up and away from the shell. Match the two edges together and then push them down flat against the metal. They will compress together, giving a very tight fit. The first layer is now locked in place (like the arch of a bridge). If for any reason you end up with a gap between the ends of the roll, fill it in with ceramic fiber.

11. Installing the second lining

Cut the inner layer of refractory blanket at 33-inch, roll it into a 13-inch long cylinder, and insert it. Unroll and install it as you did with the first layer (any excess blanket protruding out of the front opening will be trimmed later). This layer is not centered. Instead, keep it about 1/2-inch short of the back opening of the forge. You will be placing a piece of fiberboard there, and it will be cut oversize so that it is trapped in the niche this creates. With the second layer pressed tightly against the shell, cut off the excess fiber even with the other opening.

Warning:

New refractory fiber blanket and rigid board are made from alumina and silica. The fiber starts to form cristobalite (see Glossary) upon reaching 1600°F. There is a lot of perfectly reusable fiber taken out of industrial furnaces. It looks like new fiber and works just fine. However, if you want to use it, you should replace the paper mask with a NIOSHA/MSHA approved and properly fitted respirator. It must employ HEPA filters (see Resources list). You should also damp clean the area and launder your clothes immediately afterward and shower. New fiber gives off respirable silica dust too, but the amount is far less. Instructors or manufacturers who have repeated exposure should also adopt these stricter safety measures. People working around clay dust, frit, raw batch, or glazes should follow them also. Rigidizer reduces much of this risk but can present its own hazards.[14]

12. Installing the kiln shelf

Stuff excess ceramic fiber blanket (or board) in the forge bottom over the fiber layers, forming a "pillow" for the kiln shelf to rest on (ceramic fiber shreds easily to fill voids). Place the kiln shelf over it. Slowly pass the kiln shelf through the forge, while temporarily pressing the refractory fiber back out of its way. Make sure the shelf is resting on, or very near to, the bottom flats of the forge shell opening. Crush the ceramic fiber blanket down until it does. If you can easily push the kiln shelf unto the flat bottom of the shell using one finger, it is near enough.

Rest the shelf on the shell with the far end protruding 3/4-inch beyond it. Mark a line at 3/4-inch beyond the near side opening that is 3/4-inch beyond the center of the shell flats. Using the thin grinding blade edge, carefully move back and forth along this line until the shelf is cut completely through. Then, use the grinder to dress up the ragged edge and to round off all four corners. Use sanding paper to smooth away the top and bottom edges. Remember to use the dust mask, especially while grinding. Save the cutoff piece for interior baffles.

13. Making an opening for the burner

Use the burner, with the nozzle mounted, like a cookie cutter to push through both refractory layers at the burner collar opening. While pushing the ceramic fiber blanket up against the shell with one hand, cautiously push the burner through by twisting it back and forth. The material will form a tunnel. Next, push the inner layer of material into itself, widening the tunnel until it is about 1/2 to 3/4-inch larger than the outside of the burner nozzle. If you can form a taper, that is all the better. After heating up the forge a few times, the ceramic fiber will take a "set". Later, the burner will be partially withdrawn back into the liner about one inch in order to help protect the SS nozzle from the forge's high interior temperatures (save the "plug" of cut blanket). After partially withdrawing the burner, coat the tunnel section beyond the nozzle with ITC # 100 as a protection against the burner's flame.

The burner collar must be sealed against secondary air. This is most easily done with a flat washer trapped on the burner's tube. The washer slides down the burner tube and becomes a cap on the end of the burner collar. It holds a ceramic fiber plug (shredded pieces) trapped between it and the burner's thumbscrews. This system allows the burner to be aimed while still maintaining a good seal.

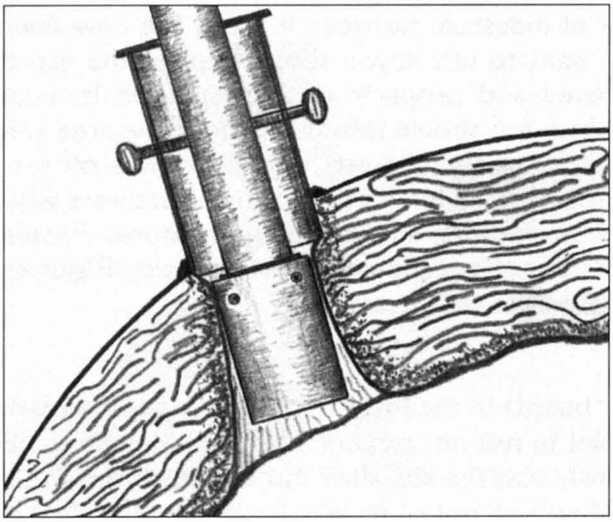


Fig. 5-8 A cross section of the forge and burner collar showing the burner nozzle sitting just inside the pushed back fiber blanket; it has been forced into a taper. The darkened area near the inside surfaces represents penetration by Rigidizer. The thick black line of the inner curve is an ITC # 100 coating. When the burner is pulled further back, this layer is extended into the tapered area. Two of the thumbscrews are shown holding the burner in place. Note the greater shell penetration of the collar on its upward side. After the burner is pulled into permanent position, a layer of loose fiber should be stuffed between the thumbscrews and the washer placed on top, sealing the burner.

14. Cutting and placing the first end board

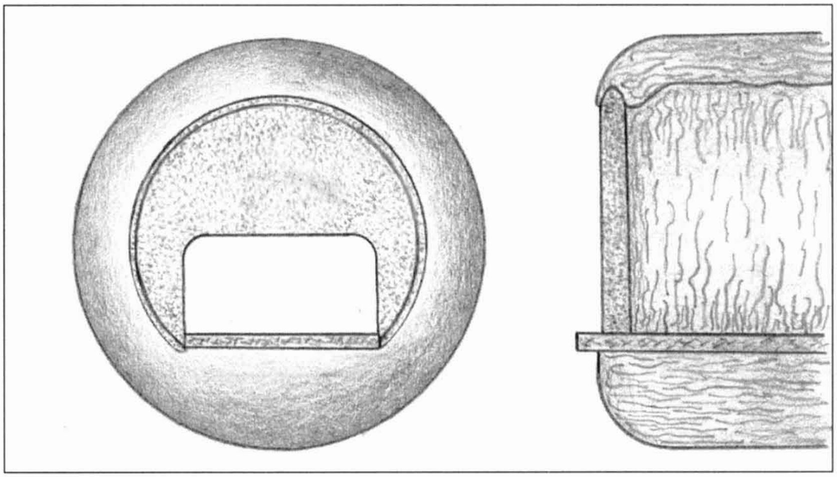
The board can be cut with a dull knife, but a fine toothed hacksaw blade works best. Press the board up against the edge of the opening with the board's flat edge resting on the kiln shelf. This will leave a faint impression in the board. Draw a line about 1-

inch outside the impression all the way around the curved line. Draw a parallel line 3/4-inches above the board's flat edge. Draw vertical lines at 2 1/2-inch either side of center for a total opening width of five inches. Use the large flat washer to mark for rounding off the inside of the upper left and right corners.

Make your cuts on the outside of the lines with the board supported. Save all your scraps in a plastic bag for repair work if necessary. Gently rub all the edges of the board with a gloved thumb until they are rounded off. Do this over a clean surface and save the rubbings too. Rub a beveled edge on the outside face of the circular area so that it will more nearly conform to the curve of the forge shell.

Push the inner layer of ceramic fiber blanket up and away from the rear forge opening, to create a pocket in which to trap the ceramic fiber board. Slide the kiln shelf several inches away from the rear opening. Carefully insert the ceramic fiber board into the pocket from the other opening while forcing both layers of ceramic fiber blanket temporarily further back out of the way. After the end piece is installed, the ceramic blanket will spring back trapping the part in place. Move the kiln shelf back into position while gently lifting up on the fiberboard.

Fig. 5-9 On the left, a view of the fiberboard end-closure. On the right, a cutaway view of it trapped in place by the fiber blanket.



If you break off a piece of the board, cement it back on with bonding mortar. Fill in any voids with slurry made of Rigidizer or mortar and ceramic board rubbings. Build up the damaged area with multiple coatings about 1/8-inch thick and allow the area to air dry between coatings. Paint the outside area of the board (on this end only) with the bonding mortar. As little as 1/2-inch over size on the curved area will work, but once the blanket fibers take a set and lose their spring the board will fit loosely. This isn't important, but it is irritating. If you soak the fiberboard in Rigidizer and then bring it to red heat, the enclosure will be greatly strengthened.

15. Coating the forge interior with ITC # 100

Before applying the coating to the forge, gently tilt it back on its legs while supporting the kiln shelf (to keep it from sliding out) until the back of the forge comes to rest on the supporting surface. Begin the coating application at the back of the forge (which is now at the bottom) and work your way forward.

The ITC #100 is thinned with water following the directions on the bottle. Apply a super thin coating. Lightly wetting the ceramic fiber blanket and ceramic fiberboard before applying the coating will improve job quality. Penetration of the ceramic fiber blanket surface is desirable, and a thick coating over the lining surface is to be avoided (ITC # 100 has a tendency to peel if it is put on too thickly). Pre-wetting helps with both of these factors. With patience, you can do four forges from a pint bottle this way. More importantly, the thinner the coating, the better it wears. Using Rigidizer instead of water to pretreat the fiber will give a toughened boundary layer, greatly reducing the tendency of the fiber blanket to shrink and cause of spalling (the zirconia layer peeling away from the fiber blanket). If you use the Rigidizer, keep it away from the door pocket and burner collar. Do not use it on the kiln shelf.

Using a new brush, daub the ITC coating on the ceramic fiber blanket (daub it straight on; do not use brush strokes). Next, brush the coating unto the Ceramic fiber board and kiln shelf. Leave both coatings 1/2-inch away from the burner opening. This allows some flex for burner movement without cracking the brittle coating. Leave the coatings 1 1/2-inch away from the front opening for the same purpose. After enough use for the fibers to take a set, move the coatings to within 1/2-inch of the door.

16. Cutting and placing the front ceramic fiberboard

This piece is cut similar to the rear ceramic fiberboard, but there are some differences because this part will become a door, rather than a permanent enclosure. Having a door on one side of the forge allows easy access for inspection and repairs. Soaking the door in Rigidizer and firing is also highly recommended.

With the flat side of the fiberboard resting on the kiln shelf, press the board against the edge of the shell opening. This will leave a line in the material which is a perfect match for the opening that the door must fit within. Cut just inside the line. Remember that the door will fit perfectly one way, but may not fit at all if it is turned around.

The opening on this door is deliberately made with a different shape than the other end to allow a greater number of forms to be inserted into the forge for heating. Either opening can be used with equal ease.

Using the dividers mark a 4-inch circle at the bottom center of the board, and draw vertical lines up from the flat bottom to the outside of the circle. Cut the opening and round off its edges. Gently check the door for fit. It needs to clear the shell opening with about 1/16-inch to spare because later it will be pushed through the shell (after being coated with bonding mortar). It then compresses the ceramic fiber blanket for a tight fit.

Paint the outside face of the board with bonding mortar and let this air dry. Rub away the sharp edge of the inside face of the board and paint the rounded rim and outermost 3/4-inch of inside face with bonding mortar and let it air cure. Paint the rest of the inside face and the edge of the opening with ITC #100.

After applying the reflector coating allow the door to dry thoroughly. To cure the

ITC coating use the burner or a hand torch to slowly raise to orange heat. This prevents the new coating of the door from sticking to the ceramic fiber blanket in the forge. Bonding mortar will air cure, but ITC #100 must be heated to cure.

You will notice that the door will not fit very far into the opening at this point. The next step is to cut a recess into the Ceramic fiber blanket, about 3/4-inch deep, so that the door will fit into the pocket and may compress the ceramic fiber blanket another 1/8-inch to 3/16-inch. Fitting the door into a pocket gives it a more protected position. First trim any protruding blanket even with the shell opening. then, cut into the side of the fiber blanket with a small paring knife or pocket knife. Use the edge of the shell as a steady rest for the blade and cut straight into the end of the blanket. Use the thin strip that is removed to stuff between the burner and the collar before lowering the flat washer into place. Fill in any voids around the kiln shelf at the openings with slurry, making sure these areas are heat cured before the door touches them.

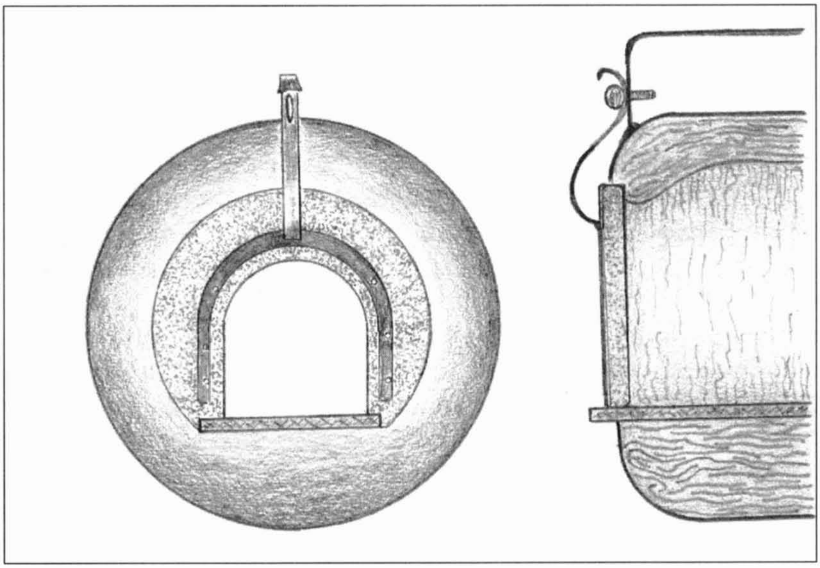


Fig. 5-10. On the left, a front view of the forge showing its door and hardware, but not the carrying handle. On the right, a cutaway view of this half of the forge shows the door inset in the forge, trapped between the fiber blanket and a "U" shaped bracket. Short SS wood screws pin the fiberboard door to the bracket. Rigidizer will strengthen their hold on the fiber.

17. Curing the forge

The forge must be left to air dry for several days in warm weather in order to give most of the water content in the ITC #100 time to evaporate from the ceramic fiber blanket. Even after the interior looks dry there is some moisture content still trapped in the fiber lining. This must be slowly cooked out to prevent it from suddenly turning to steam and damaging the ITC #100 coating. After placing the door gently into its recess, prop something that can withstand heat on either side of the door. This is a precaution against the exhaust gasses blowing the door out of the opening and damaging it.

Run the forge on the burner's lowest stable setting for five minutes, and then shut the forge down allowing it to cool. Do this four times. The fifth time run the forge up to orange hot inside, then shut it down and allow it to cool completely. Finally, run the forge for thirty minutes at orange hot, then run the heat on up to yellow. The forge is now properly cured. Remember to use the flat washer and choke to protect the burner from forge heat even during curing sessions (see Maintenance and Operating Instructions).

After a few days the burner is partially withdrawn back into the ceramic fiber blanket about one inch to help protect its nozzle from the forge's high interior temperatures. The collar is sealed at this time by installing the ceramic fiber blanket shreds within the burner collar between the thumbscrews and the flat washer.

Finally, the remaining area surrounding the collar opening and the one inch of exposed ceramic fiber blanket beyond the nozzle are coated with ITC # 100, and the curing procedure is repeated. This is done to keep the burner from destroying the Ceramic fiber blanket at the burner opening. Presoaking the area in Rigidizer is highly recommended.

18. Using the forge to build exterior parts

Being a movable part, the forge door needs some support and a method of locking it into place. With the door gently propped closed on the forge, heat and form some of the flat bar into a "U" shape the hard way.

The flat bar will be hammered around the horn of an anvil, leaving a generous amount of excess length in the straight ends. If you don't have tongs to hold the flat bar for hot work, use the locking pliers. If you don't have an anvil yet, suspend the area to be bent between two supporting pieces of metal and hammer on the unsupported middle section while moving the work piece around until the "U" shape is made (or hot bend it around a pipe.)

Flatten the "U" when it's cold and drill four to six equally spaced holes for SS wood screws. Although the screws will tear out of the refractory quite easily in the beginning, after a while the ceramic fiberboard will take a set around them, and they become firmly anchored in it. The screws are optional since the door will stay put even without them.

Center the "U" on the door and mark the straight sections for cutting, leaving them about 1/2-inch away from the door's bottom edges and remove the excess stock. Form an "S" shape from flat bar, and attach it to the top of the inverted "U". Cut a two-foot piece of flat bar then bend and weld it positioned vertically on the shell top and aligned with the "S" shaped bar.

Drill a 13/64-inch hole through both bars while they are pressed together. Tap the forge handle bar for a 1/4 x 20 thumbscrew and drill the hole in the "S" out to 5/16-inch. The fiber blanket has a good deal of spring to begin with, but it will shrink back under heat and pressure so that the board moves further in. The door support will have to be adjusted several times in response to this tendency. Finally the door will fit firmly in one place. Once the position is reached, paint the rest of the fiber blanket with ITC # 100 to within 1/8-inch of the board.

Fastener assembled version

The exterior parts are bolted and screwed to the forge shell of this version. Chapter

8 has a fastener assembled furnace, with a different method for fastening the burner collar; supplement your understanding by reading that section.

Supplementary Parts List:

(1) A dozen 6 x 20 x 3/4-inch self-drilling sheet metal screws
(2) A 1 1/2 NPT locking nut
(3) Replace the 1 1/2-inch x 3-inch long pipe with a pipe nipple (same size)
(4) Four 3/8-inch locking washers
(5) Four 3/8 x 16 x 3/4-inch bolts (no shoulder) See Chapter 9, step 7 for a threaded alternative.

Supplementary Tool List:

(A) One 3/8-inch drill bit
(B) Two 1 1/64-inch drill bits

19. Making and attaching the burner collar

Begin by cutting off one threaded end of the pipe nipple you will be using for the burner collar. Its other threaded end will be screwed into the locking nut, which can then be secured to the shell with the self-drilling screws through 1 1/64-inch holes made near its hex points.

The under-side of the nut is ground into a concave surface to match the curved side of the forge shell and the weld seam is ground flat in two places where the nut overlaps it. The nut can be held for grinding by first screwing it down snug on the pipe nipple and grinding away the protruding threads. Using the angle grinder to dish out a concave shape isn't hard. The blade is held at a low angle to the work so that its curved outline is depressed into a larger diameter, matching the larger diameter of the shell. How much angle, is found by trial and error. Frequently checking the nut against the shell will allow a near perfect fit after a few minutes of grinding.

If you want the burner collar placed at an angle, then the concave face is tilted to one side. The amount of grinding and checking is almost the same. Just make a mark in the center of the kiln shelf and use it as a target. The pipe nipple then becomes your "site" for lining up the burner's aim. The aim doesn't need to be perfect because

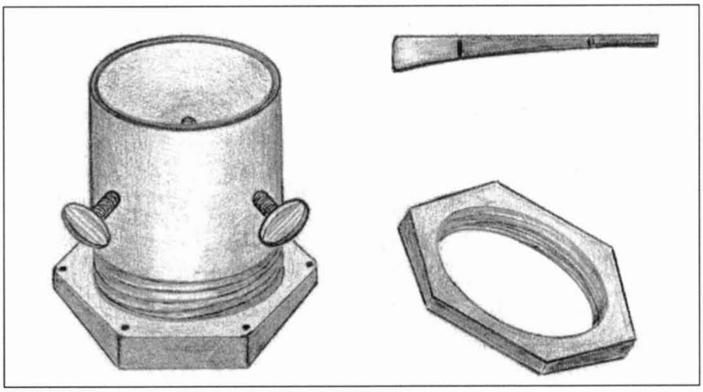


Fig. 5-11 On the left, a burner collar and close nut. Note the holes for self-drilling screws near the nut's corners. On the right, two views of the tapered and curved nut.

the burner can be re-aimed using the thumbscrews. Grind a taper on the bottom face of the nut, leaving it 3/16-inch thicker on one side than the other and continue with grinding the concave surface as previously recommended.

20. Attaching the legs

Follow the directions in Step 8, but mark the leg positions by inking the hexagonal outline of the coupling nut where it touches the forge shell. Then, mark cross-lines from the hex points and center punch. Drill pilot holes and then enlarge them to 3/8-inch. Attach the coupling nuts using the short bolts and locking washers. Lock them down tightly. Remember that you won't have ready access to retighten them later if they should loosen up. If you decide to braze the inside bolts in place, be sure to remove their zinc layer where you want the braze to adhere. Also, carbon-black the thread to make sure the braze doesn't stick to it.

21. Attaching the door parts

Use two bolted on handles if you place the burner collar at top dead center. Also use four small curved flat bar braces fastened to the forge body by sheet metal screws to hold the door in place instead of the "S" shaped part and thumbscrew. Otherwise follow the previous recommendations. The forge handle is built in a "U" shape about one foot long and four inches high. Drill two 11/64-inch holes in each of the bar's ends. Then, bend the ends at 90°angles (about 1-inch long). Use self-drilling sheet metal screws to attach the flat bar handle to the forge body afterward. Hammer the ends down to match the shell's curve.

22. Advanced design options

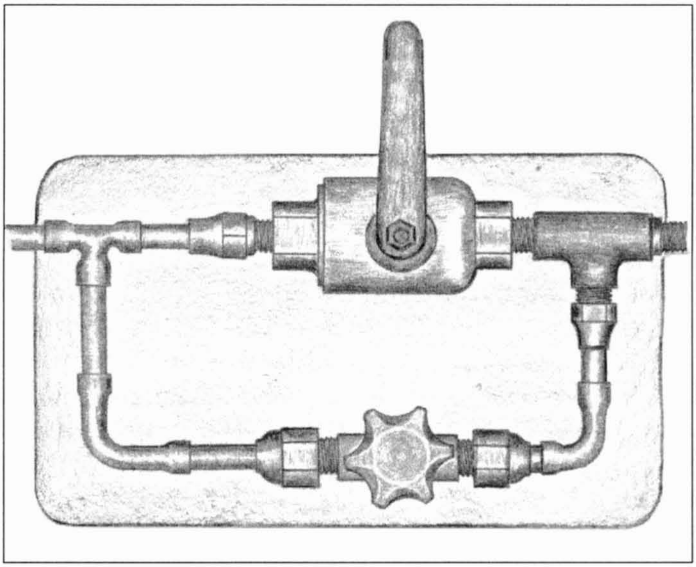
The first desirable option is a special mounting plate for the shut-off valve. It can be placed either on a forge leg or on the side of a wheeled cart that the forge and the propane bottle sit on, along with the hand torch on its own burning lead.

A 3/8-inch or 1/4-inch copper tube runs from a valve on the plate up to the burner. The first advantage here is safety because the fuel hose is kept well away from the hot forge shell. The second advantage is that it provides a stable platform for idler assembles (see Fig. 5-14).

Before deciding on any of these options, remember that you must check with your local fire department and check the building codes for your area, in order to determine safe and acceptable practices. Local authority modifies many of the recommendations in the Gas Code. What is considered acceptable practice in one place may not be approved in another.

An idler normally uses two valves in parallel, a ball valve and a needle valve. The ball valve acts as a shut-off when the needle valve is completely closed. However, with the needle valve open a little way, the ball valve becomes a kind of high/low switch. When the ball valve is closed, a lesser amount of gas is allowed to escape through the needle valve to keep the forge running at an idle while you're busy working the part. Then the ball valve can be quickly opened for full heat when the part is again placed within the forge. This will save a lot of fuel and help to keep the shop more comfort-

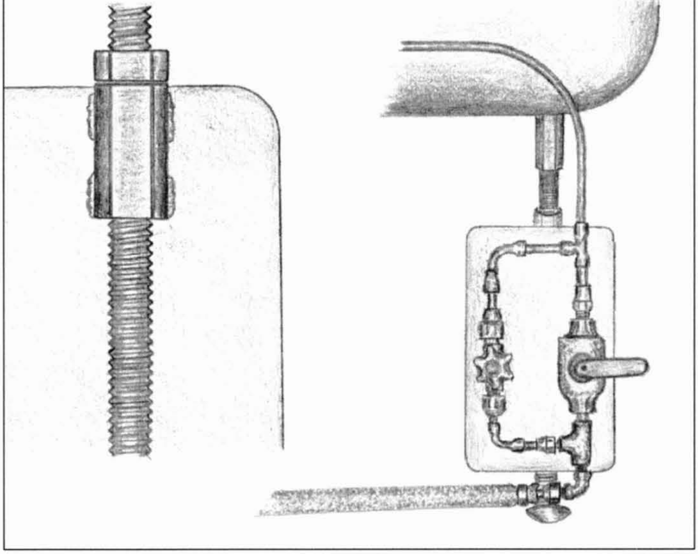
Fig. 5-12 A close up view of the double valve idler assembly with a ball valve in the upper middle of a copper tubing manifold and the needle valve below it. The upper left side shows the gas exit tube leading to the burner. The upper right side shows the threaded gas entrance ready to be hooked up to a fuel hose. Note that both sides of the needle valve and the left side of the ball valve have nuts that can be unscrewed with the manifold in place. This allows the valves to be changed out or serviced.



able in warm weather. The needle valve can be set higher or lower to keep it synchronized with different full heat pressure settings on the forge. The disadvantages of this arrangement are the complicated plumbing involved in making a miniature gas manifold and the possibility of the packing in the needle valve leaking. The main advantage over a mechanical idler is fine-tuning. It is also the standard practice.

Fig. 5-13 shows an example of the many ways there are to set up the two valves. The main thing to be remembered when building your own version, is to make sure you leave room for the fittings to screw completely off so that the valves can be cleaned or replaced if necessary.

Fig. 5-13 On the left, a detail of the coupling nut welded to the back side of the idler assembly plate, with a locking nut above the plate's top edge. The coupling can be welded brazed or screwed on, and its thread chased with a tap. On the right, a section of the forge with the assembly mounted on a leg. At its top, a copper tube heads toward the burner. At bottom, an elbow holds the fuel hose just above the head of the carriage bolt. It is wise to employ a protective cover on the hose for a couple of feet. Gas manifolds should never be mounted on the heated forge shell, but rather on a leg or on the side of a cart.



Brazing the manifold together with all the parts in place is the easiest way of making sure everything will fit. In order to protect the valves from heat, open them fully and partially submerge them in water (remove the handle from the ball valve during soldering). This method forces you to clean and prepare the two sides of the manifold separately, and then braze them in two stages. The control gained is worth the extra effort. Remember to blow-dry the manifold afterward (see Fig. 5-16).

22. Single ball valve idler assembly

When a ball valve is mounted on the burner, it is only used as a shut-off. By mounting the valve on a separate plate and having the valve handle rest against a movable stop, it can also become an idler valve.

To make this assembly, you should start with a larger size valve than you would use if it were mounted on a burner. The point here is that the bigger valve will have a larger handle and a stronger valve stem. The valve is mounted on a steel plate by trapping it with steel “U” bolts.

A small bolt, with it’s head cut off and replaced by a piece of flat bar for a handle (or part of a small “C” clamp as shown in fig 5-14) runs up and down in a slot. A nut and washer on the bolt force the movable plate on the backside up against the mounting plate to lock the bolt in position. With the bolt loose, the back plate moves

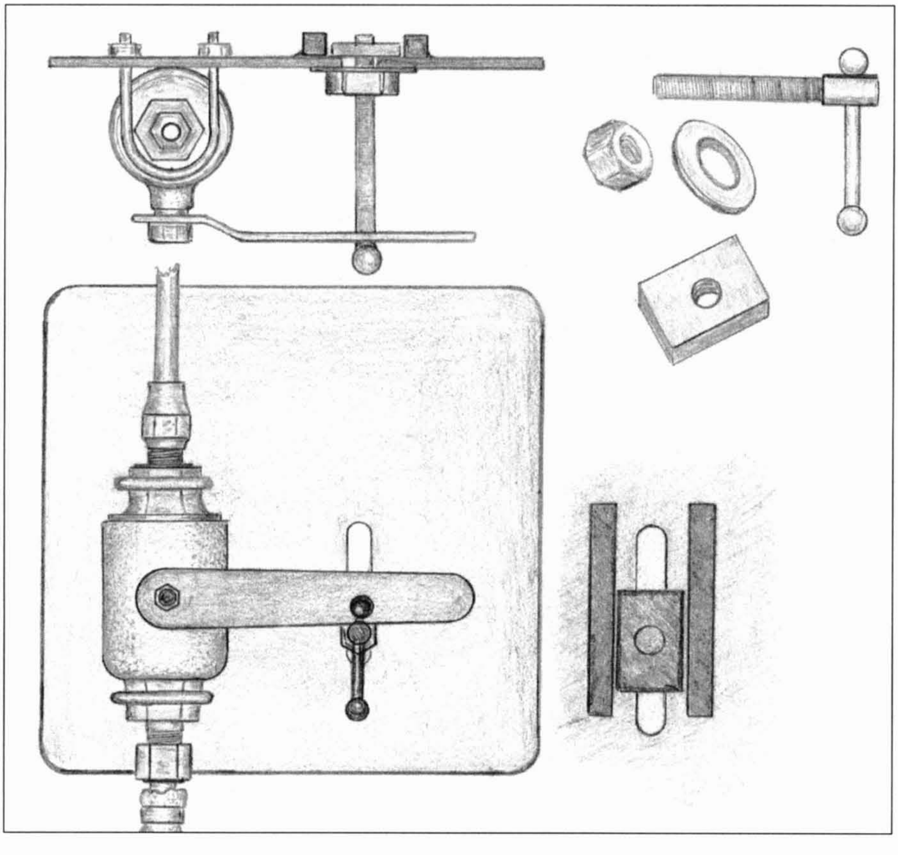


Fig. 5-14 The mechanical idler assembly is displayed in front and top views on the drawing’s left side. The valve handle rests atop the threaded handle from a “C” clamp. The top view shows how the locking nut presses a sliding plate tightly against the back of the mounting plate, locking it in any desired position within the range allowed by the slot. On the lower right side is a detail showing the sliding flat bar trapped between two permanently affixed square bars. On the upper right side, the four moving parts of a movable mechanical stop are shown.

vertically, while the two square bars prevent it from spinning. This provides a movable stop for the valve handle, allowing the idle setting to be adjusted so as to be adequate for different full pressure settings. The mechanical stop is dropped to the bottom of the slot when shutting down the forge.

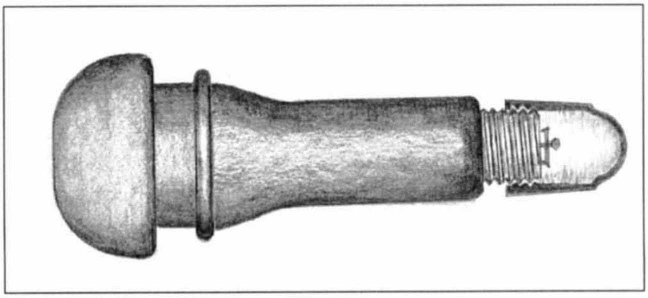
No sizes are given, because everything is dependent on the valve size. I would suggest a three-inch "C" clamp for parts though. Once you have everything adjusted on the sliding arm, drill and pin the nut or silver braze it to keep it from moving. Also a double nut arrangement can be used to lock the nut in position.

Using a ball valve in the partially open position is not considered good practice because the valve can degrade from wear as the gas moves past it. However, you are only running a few pounds pressure on a regulated system. Parallel valves are considered the correct way to do the job. The choice is yours, but you need to check with local authority to see if either method is allowed in your area.

The tube can be made adjustable by running it parallel to the curve of the forge shell a ways and then bending it upward to make a giant "L" shape. The point is to deliberately provide excess tubing so that the burner can be moved up later (see curing the forge section). This also prevents any possibility of temperature changes or physical stress causing the gas connections to be loosened. Make sure the tubing is kept about two inches away from the forge body in the parallel section of the run (to avoid heating the fuel).

Use compressed air to blow any metal shavings or dirt out of the copper tubing before final installation. Blowing out the internal parts can be accomplished without the use of your own air-compressor. You can use a bicycle pump. In order to do so you will need an adapter, but there is no need to make one. Just go to an automotive tire store and buy a tubeless tire valve stem.

Fig. 5-15 The plastic cap over the thread and air valve is shown half cut away. The bulbous protrusion on the other end is hard rubber. This is a typical tire valve. The valve itself uses a 1/8–inch standard pipe thread on one end and a standard spring-loaded internal air valve. It is called a tank valve when sold without the outer rubber covering. A tank valve will screw directly into the end of a standard air blower if you wish to employ it that way.



It has a rubber base to seal against different part shapes, a plastic cap to protect it from dirt, takes up almost no space in your toolbox, and is inexpensive. Remember that any metal shavings will be blown out of the tubing at high speed, so be careful about where it is pointed. Do not use the compressor at a gas station with this tool, because there are no vent holes beyond the rubber face of the stem. It will deliver full pressure to the part and thus does not meet safety standards.

Copper tubing with flared or compression fittings has been considered standard practice for connections on the low-pressure side of regulated lines in the past, but you must check with your local authorities to make sure they are still approved in your area. Further, you must find out which one of these two types of fittings your local codes call for.

With the forge mounted on top of a handcart, you should build hangers inside the cart to store two coiled fuel hoses. Buy a "T" fitting and install it on the forge cart. Run the copper tubing from one opening up to the forge, and the other openings to the fuel hoses.

The regulator is kept on the fuel cylinder and is linked to the cart by one of the fuel hoses. When the forge is used, after transport to a job site, the tank and regulator are brought out of the cart and placed at a distance from it.

The other fuel hose has the 1/2-inch hand torch connected to it. It can be used to light the forge and preheat the anvil while most of its lead is left coiled in the cart. When it is being used for silver soldering or tempering the whole line can be uncoiled so that the cart may be left at a distance, and the tank may remain in the cart on a job site.

Black propane hose is not very flexible. This makes it a poor choice for use with the hand burner, but standard burning leads are not rated for propane. However, for about $4 extra you can buy burning leads that are a rated for propane. These two different kinds of burning lead look exactly alike accept for the identification letters printed on the hose. Make sure to ask for the propane rated type.

Once the brass collars are removed from the ends of the lead, the oxygen hose will easily peel away from the fuel hose. The oxygen lead can be saved for use as a compressed gas lead for welding machines or for use with an Oxy-fuel torch and propane gas. The fuel line can be hooked up to a fuel-to-pipe fitting connector on the "T" fitting to be used with the hand burner. Since the burner leads are about 25 feet long, you actually end up paying no more per foot than the regular propane hose would cost.

The proper procedure for safely starting and running the forge:

(1) Make sure the burner valve is closed and the burner choke is part way open.

(2) Open the tank valve completely.

(3) Open the regulator to six PSI.

(4) Ignite the 1/2-inch torch or a small portable propane burner and insert the flame well inside the forge opening. Aim the burner at an angle and keep your hand out of the path of the hot exhaust.

(5) Open the valve to the burner, but keep your hand on it. Sometimes you won't get an immediate ignition. If you don't, close the valve but keep the flame inside the forge. Reopen the valve and try again. You could repeat this procedure frequently without danger from gas build-up.

(6) Extinguish the hand torch by closing the ball valve that feeds gas to its fuel hose. This allows the positive pressure to equalize with ambient air until the flame snuffs out; then close the valve on the burner.

(7) After ignition give the forge a minute to warm up then completely open the burner choke and set the gas pressure wherever needed to do the work. Remember to keep the pressure high enough to get a complete burn. When using the idler system, the

forge should still be kept running at high enough pressure so that the exhaust flame is no longer blue.

(8) Wear UV protection. With these burners, your forge will turn an incandescent yellow-white at higher gas pressures. This creates the danger of flash burn if you peer into the forge without dark glasses. To determine how dark is sufficient, close your eyes after looking. If you get an after-image, the glasses aren't dark enough. If you spend much time looking into the forge you're going to need a darkened face shield or sunscreen ointment to protect your skin. It is best to use your watch and time the heats instead of checking the work visually.

(9) Make certain the forge is properly secured to prevent it from being knocked over while it is running or during cooling.

(10) To safely shut down the forge, close the tank valve completely, then wait for the burner to run down and go out. As soon as this happens, close the burner valve and shut the choke completely. Failure to shut the choke will result in heat damage to the burner from hot gases backing up from the forge and exiting through it.

(11) Finally, back the regulator off completely (turn the pressure adjusting screw counter-clockwise until it moves freely). This leaves the whole system with an atmosphere of propane in it (so there is no need to purge it), but without positive pressure. Wait until the forge cools down completely, and then double check the valves to make sure they are closed, before leaving the area.

(12) Never leave a forge or torch running unattended.

Tuning the forge

Once the forge is warmed up, the exit flame should have a yellow color. Blue flame is a sign of incomplete combustion. If your forge doesn't normally show blue flame, than you are most likely running it too low and should turn it up. If this has no effect, remove the burner and check it for obstructions (especially the gas accelerator orifice).

If the blue flames are a constant problem, widen the forge openings. Remember that the venturi effect is not a strong force. If you bottle up the exit gasses, you can force the burner to run a reducing flame just as though you had made its air slots too small. Once the burner is installed in the forge, you must think of them both as one system.

The exhaust gasses are spinning and expanding as they leave the forge. This means that some of the spent gasses are already leaving the forge at close to right angles. It takes only a mild breeze to bend their trajectory a little more, thus feeding some of the oxygen depleted gasses into the burner intakes. When working outside or in a drafty area, position the forge to avoid this. If it starts running erratically, shift its position or shelter it from the wind.

During the drying process it isn't surprising to experience interference from water vapor. It can even blow out the burner flame. Encountering the problem again after long periods with the forge sitting idle in a damp climate can also be expected.

Even with the forge running fiercely, you can place your hand in front of the exhaust as little as two feet away. This is because hot air rises and is not due to the heat dissipating in that distance. If you raise your hand, it will burn. The point is that appearances are deceiving. You can't see the super heated gasses rising, and you won't see a wooden wall being dangerously dried out from the forge running a few feet away from it. Nevertheless, both of those things are happening. If you don't protect the back wall and ceiling it can suddenly explode into flame without any period of smoldering first.

Maintenance

Most of this section was covered directly or by implication in various sections previously. It is necessary to keep the burner entrance sealed as much to protect the parts being forged from oxygen infiltration as to isolate the burner air intakes from spent gas during operation and to stop the chimney effect after shut-down.

It is important to avoid overheating the burner nozzle. This requires the nozzle placement to be recessed about one-inch back into the refractory lining in order to shelter it from the high interior temperatures of the main forge chamber. It means keeping a watchful eye on the burner nozzle to make sure it isn't being overheated sagging out of shape or burnt up. A sudden shower of very fine sparks coming out of the forge exit is a danger signal which may indicate one or both of these occurrences in progress. If you run your forge high enough to encounter these problems, you need to consider switching to a boron nitride coated mild steel nozzle or the use of a ceramic burner port.

Obviously, gouges in the ceramic refractory lining or end enclosures must be repaired immediately. Cracked kiln shelves should be repaired with bonding mortar or replaced if needed.

The forge should be sheltered from the weather. If it can't be stored in a warm dry place, consider wrapping it (when completely cooled down) in a watertight tarp. Dampness is bad for every part on and in the forge. If the forge does get wet, use the same formula to dry it out that you employed to cure the refractory coating in the first place.

6

Building a Forge Cart

The forge cart was originally designed just for convenience in storage and handling of a portable forge; however, it became clear that many smiths did not consider a tube forge sufficiently flexible to replace their open coal forges (the tube forge is featured in Chapter 5). There was also a great deal of interest in the refractory tabletop as a movable hot-work surface for metal and glass artists. Since the cart is an obvious platform for temporary brick heating structures and clamshell forges, it has been designed to become a mobile hot-work station. You may decide not to build all the following features. Even so, the cart's general construction will provide a good plan to follow; just delete the features of no interest.

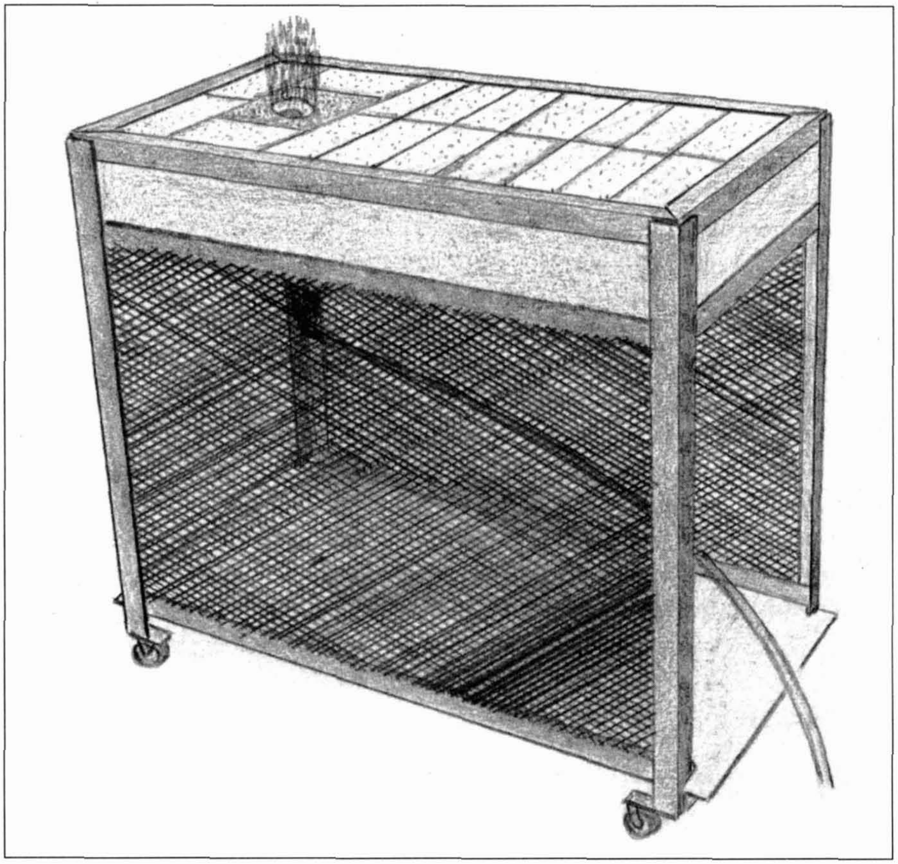


Fig. 6-1 Even without forges mounted this cart is a general hot-work station. Note the depth of insulated tabletop, from which the flame emerges.

The cart uses 1/8 x 1 1/2-inch angle iron for its frame because that size provides sufficient strength without excessive weight. Angle iron lends itself well to this kind of construction and it is the most economical of steel forms. The sheet metal for the shelf bottoms can be steel or aluminum. It should be heavy enough gauge to support the load to be placed on it. The sheet metal in the tabletop's sidewalls should be steel. Aluminum sheet metal could lose its temper (and thus most of its strength) near the hot brick face. Aluminum is a better choice for the shelf bottoms. Tempered aluminum and mild steel run about even pound for pound in shear strength but the greater cross section of the thicker aluminum plate provides better rigidity.

This cart is shown fastener assembled, but can be welded together. It is three feet long, but the forge faces across its length because the exhaust gasses would otherwise heat the tabletop and any accessories mounted on the cart. Space between the two types of forge is used to rest hot parts or to do silver brazing and heat coloring. Both forges can be removed and more insulating bricks can be stacked into temporary heating structures on the top shelf in order to accommodate the occasional piece, which is too large to be contained within the portable forge. A clamshell forge can also be attached to the tabletop.

The cart's refractory top has a throughway for the vertical burner collar. The table also segregates the forge and hot work from the hoses, which hang a few inches below the top shelf, protected from physical damage by the cart's frame and expanded metal screens. The tank is taken out of the forge cart during operation and moved to the minimum safe distance from the forge required by governing codes. OSHA requires a minimum of twenty-five feet. Other codes require the tank to be placed outside of enclosed spaces. The tank and regulator are connected to the rest of the system by their own hose. Don't leave the tank in the cart when the forge is in use or when the cart is stored inside.

Read this entire chapter before you start construction; then decide if this size is going to be sufficient for all of the accessories you want to build. Simply adding any desired width to the existing dimensions would increase the length and width of the cart. An example would be an increase from the nineteen-inch width to two feet. Part # 9 would increase in length from 18 1/2-inches to 24 1/2-inches. So the materials list can quickly be adjusted to reflect a dimensional change. All 19-inch plus angles are width, 40-inch angles plus are height, and 30-inch plus angles are length. The same holds true for the shelf materials.

Item #10 is used for the legs. This cart is designed for two-inch wheels and the comfort of a six-foot person. Larger wheels and shorter stature should be subtracted from this figure. The length and width dimensions given, work out well with the standard brick size chosen. So, if you change the dimensions the keep brick sizes in mind. The ability to transport a cylinder inside the cart is less important than comfort when using this equipment.

Materials list:

(1) Three cans of red polyurethane spray paint and one can of black barbecue spray paint [1]

(2) "T" fitting, (refer to Chapter 2), two ball valves and other parts required to make the fuel hoses work
(3) One 1/4-inch type "T" Oxy-fuel hose
(4) One type regular propane hose long enough to allow it to hook up to a cylinder stored outside
(5) 1/4-inch copper tubing, about 4-foot length.
(6) Two swiveling castor wheels and two rigid castor wheels (see Resources)
(7) Six 1/8 x 1 1/2 x 1 1/2-inch steel angles, 35 3/4-inch long
(8) Six 1/8 x 1 1/2 x 1 1/2-inch steel angles, 18 3/4-inch long
(9) Two 1/8 x 1 1/2 x 1 1/2-inch steel angles, 1 1/2-inch long
(10) Four 1/8 x 1 1/2 x 1 1/2-inch steel angles, 40-inch long
(12) Two 1/8 or 3/16-inch x 1 1/2-inch flat bars, 29 3/4-inch long
(13) One piece of 3/16 x 18 1/2 x 35 1/2-inch aluminum sheet
(14) One piece of 3/16 x 18 1/2 x 39-inch aluminum sheet
(15) Two pieces of 16 gauge expanded and flattened metal 24 1/2 x 35 1/2-inch
(16) Two pieces of 16 gauge steel sheet metal, 6 x 35-inches
(17) Two pieces of 16 gauge steel sheet metal, 6 x 18-inches
(18) One box 3 1/2 x 4 1/2 x 9-inch insulating refractory bricks [2]
(19) Small sack or a gallon pail of air setting refractory mortar mix (see Step 9).
(20) 1 x 18 x 35-inch calcium silicate board or alumina fiberboard
(21) Fifty count boxes of #10-32 x 3/4-inch machine screws, washers, two boxes of nuts, box of self-drilling screws (close to the same size)
(22) One cubic foot of Perlite [3]
(23) Brass shower drain [4]
(24) Steel or SS tube to match the ID of the shower drain and 4 1/2-inches long [4]
(25) 2 x 3/4–inch threaded reducer [4]
(26) Four 1/4-20 thumbscrews, 1 1/2-inches long
(27) #8 or #10 set screw
(28) 3 linear feet (forty-two inches) of one inch thick, 8 # ceramic fiber blanket (rated for 2300° F) from a 24-inch wide roll. Or 1 1/2 linear feet of two inch thick.
(29) Mullite tiles are recommended as a hard facing instead of the soft insulating brick. They should not be less than 1/4-inch thick or more than 5/8-inch. The Perlite layer allows for adjustment to thickness.

These materials make a strong special purpose cart. If the cart is going to travel a lot, then it might be worth your while to redesign the tabletop with lighter products (i.e., alumina fiberboard and rigidizer coating). Likewise, the steel can be replaced with aluminum and the standard wheels with lighter kinds. A busy shop owner might replace the cart completely, with a portable stand such as are popular for cutoff saws if the forge is mainly planned for field use.

Tool list:

(A) Electric hand drill with three 3/16-inch drill bits, 13/64-inch bit, a # 3 bit, and a 1/2-inch countersink
(B) A 4 1/2-inch right angle grinder (cutoff wheels recommended)

(C) Welding machines are the practical way to do this much work; however, this cart is set up to be drilled and bolted together
(D) A #10-32 starting tap and #21 drill bit, 1/4 x 20 starting tap, tap handle, tapping fluid
(E) 6-foot tape measure, 12-inch combination square, ink marker, and scribe or soapstone
(F) Three 3-inch C-clamps (recommended)
(G) Small center punch or prick punch
(H) Safety glasses
(I) 2-foot carpenter's square [5]
(J) Cheap 1-inch paintbrush
(K) A 3 1/2-foot pipe clamp or furniture clamp
(L) Jig saw (recommended)

1. Assembling the shelves

Fabrication of the cart begins by assembling the top shelf. Cut both of the ends back at an angle of 45° on one flange of each of the shelf angles (one pair of the parts #7 and one pair of the parts #8). Next, deburr them and lay the parts out in a rectangle (toe in and toe up). If you aren't familiar with these terms, look them up under "Angle" in the Glossary. The second pairs of parts #7 & #8 will be cut differently for the bottom shelf.

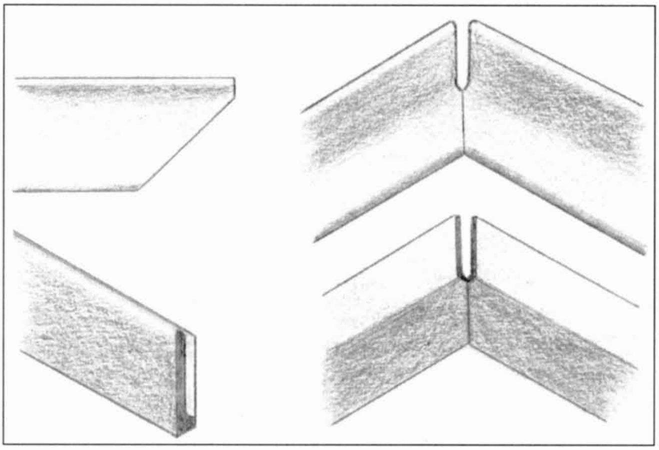
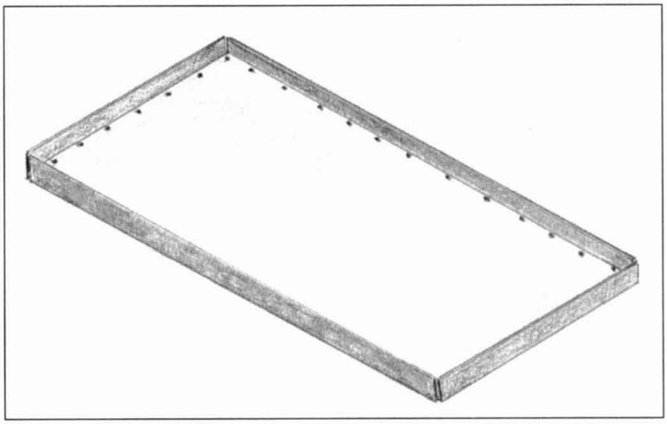


Fig. 6-2. The inside of the angle corner as seen looking down into it, is shown in the upper right corner. To its left, the 45° cutback in one flange of the angle, which is viewed toeing up and in. Bottom right is an outside view of the corner, looking up at it. To its left, the angle is in perspective looking down. It is now toed up and in. Note that the 45° cut does not form a complete point. It stops short of the other flange, creating a space in the vertical portion of the frame corners. The opening allows them to clear the web's radius on the inside of the leg angles.

Check them for parallel by comparing the width and length measurement at either end. Grind the cutbacks to adjust sizes. Then, check for square by measuring from one corner diagonally to the other (farthest) corner. Then make the other diagonal measurement. When the two measurements are equal, they are square (this is called "X" pattern squaring, or crisscross squaring). Tape around the upright sides of the corners in order to hold them in position and place the 18 1/2-inch x 35 1/2-inch piece of sheet metal inside them. Center the sheet metal and clamp the work in place. Use a clamp on each of two diagonal corners and double check the work with a carpenter's square. Then do the same on the other two corners.

Screw the sheet metal to the angle frame about every six-inches, ending about 1 1/2-inch from each of the angle ends. Check carefully as you fasten the angles to the sheet metal to make sure they aren't drifting out of square. Begin by fastening one side of a corner and do the same in the diagonally opposite corner (checking for square as you go). Then, follow the same procedure for the other two corners. Next check your outside dimensions and fasten all the other angles at their corners. Now install the rest of the screws.

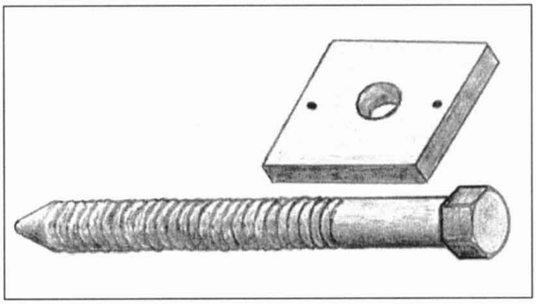
Fig. 6-3 The assembled shelf; note how the corners are not closed, thus allowing a tight fit between them and the vertical angles which will become the cart's legs. Also note what appears to be an "L" shaped line of dots. These are the screws which are along all sides of the sheet metal that covers the shelf's bottom.



2. Constructing the legs

The four legs are completely finished before they are mounted. This is done in order to assure that they will all end up extending exactly the same length below the cart. If anything goes wrong with this plan, they will still end up close enough to be evened out with the addition of flat washers between the holes on the angle iron's "tab" and the castor's mounting plate.

Fig. 6-4 A pointed 1/2 x 6 bolt and flat bar part with hole drilled in its center to be threaded for the bolt, along with two holes for machine screws on either side of the main hole. Mount the two bolts near the outer edge of the lower shelf, and far enough in to clear its swivel wheels. Attach the flat bars with their center holes drilled but not threaded. Drill through the aluminum plate and angle and then thread all three parts in position. This provides enough thread depth to secure the bolt.



2-inch cast iron wheels are ideal, but hard rubber castor wheels are good enough for the cart (do not use pneumatic tires). If you drop something hot against one of them, just nudge it away. You need rigid (non-swiveling) wheels on the forge end of the cart and swiveling wheels on the far end. If you can get two locking wheels for the swivel castors, then you don't need to build mechanical stops. Otherwise, use two short pieces of thick flat bar, drilled and affixed to the lower shelf. Then run threading through all the parts to match the long bolts. They act as breaks when screwed down to touch the floor. Any metal will do for the flat bar. You will have to add the bolts, a drill, and a starting tap for them to your supplies.

Buy castors that have a flat mounting plate at their tops, which can be bolted to the angle legs. Cut away one side of the angle, equal to the length of the castor mounting plus an extra 1/2-inch for the bend's radius and the web's thickness. Grind a notch in the cutback side to help the long side bend more tightly when folded over it. Use a cutoff wheel as your saw blade. Cut above the web on all four legs and grind them flat afterwards with a regular grinding wheel. Remember that you have a left and a right facing leg on both ends of the cart. So, when you cut away the flange on one side of the four angles, you must end up with two lefts and two rights.

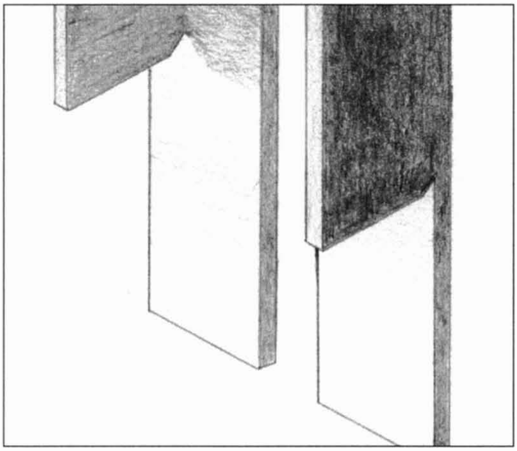


Fig. 6-5 Two angles are cut "left hand" and "right hand." It isn't important which is which. Just remember to end up with two of each kind among the four cart legs. If you imagine their extensions (tabs) bent up at 90°, they would be in the same position as they are used on the cart. Castors are mounted even with the outside of the angles with any extra castor width kept under the cart, as in Fig. 6-6.

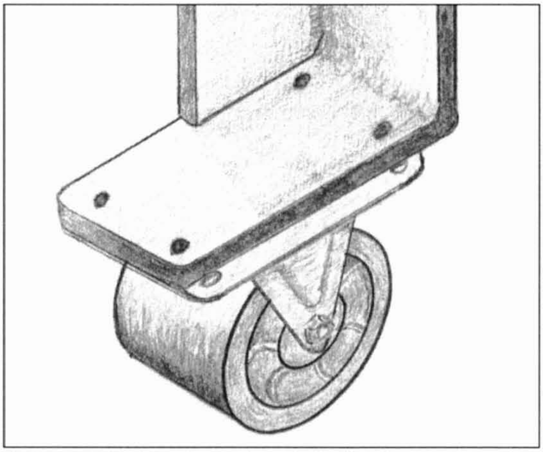


Fig. 6-6 The extended area left on the uncut flange is bent over to make a mounting face on the leg bottom. It ends up longer than the width of the flange it rests against, but the extensions on the castor's mounting plate (which hold the wheel axle) help maintain rigidity. Two mismatched holes have been relocated to fit within the flange's width. Note that the overhung section will end up under the cart.

Afterward, heat the tab in the forge and bend it over the short side. There is no need to braze the seam. Drill and thread matching holes in the folded side. Then, bolt on the castors. If the castors you choose have a wider mounting plate than the 1 1/2-inch angle can cover, drill a second set of holes in the middle of the castors mounting plate and the tab. Assemble the castors with the excess width positioned under the cart. It is important for the castor to sit square on the leg end, at least in the in the direction that is parallel to the wheel axis. Otherwise, the wheel wouldn't sit flat on the floor. Hammer, and grind the angle tab as square as you can using washers for shims if necessary.

After all castors are mounted, measure the length of the legs from the wheel edge

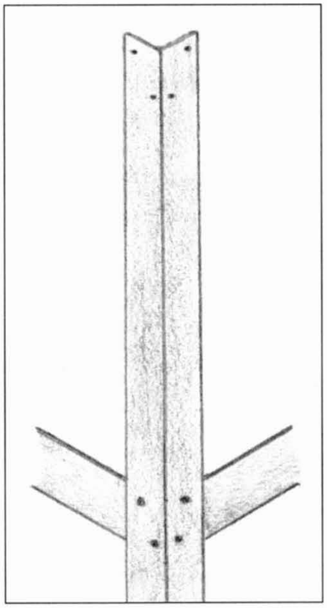


Fig. 6-7 The vertical angle of a leg extends several inches past the two horizontal angles of the top shelf. Note that only two of the four screws are put in place until the cart is squared, and then the others are installed as shown. Your angles may run a little high and/or low as you adjust leg heights in order to make all the legs the same length below the shelf bottom. Fig. 6-10 shows the quick and easy solution to this possible problem.

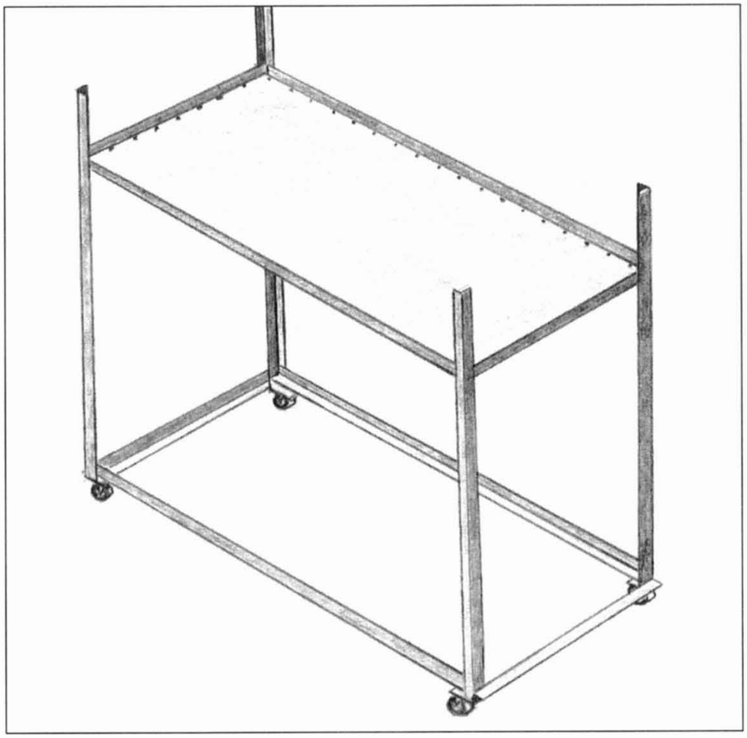


Fig. 6-8 The completed frame, with wheels and top shelf, is now ready for addition of sheet metal sidewalls and top angles. This is the first opportunity to correct any out of square fitting. The cart while be semi-ridged after the installation of the sheet metal, but installation of the screens and bottom shelf will provide a second chance to further refine the squaring process.

to the far end of the angle with the aid of a square. Cut the angles down to the measurement of the shortest leg. Drill two holes in each flange of the four angles. The upper holes are drilled at 1/2-inch from the cut end and 1/2-inch in from its edge. The lower holes are drilled at 1 1/4-inch from the cut end and in the center of the flange for later use

3. Mounting the legs, braces, and shelves

Use the square and temporary brace just as you did to keep the shelving rectangular. Measure 6 1/2–inches down one leg. Clamp it to the side angle (longest dimension) of the top shelf. Check it for square and fasten it with one screw. Clamp a leg on the other corner (long dimension). Clamp an angle (toe in and toe up), 1 1/2-inch above the wheel mountings, on the inside faces of the angle legs. Cross measure for square and fasten two screws on all four corners, this side only. Turn the cart over and repeat the process, but only use one screw in each corner of these legs and bottom angles. Remember to use rigid casters on one-end and swivel castors on the other.

Check the second aluminum sheet for square and parallel before resting it at an angle with its lower edge centered between the cart's legs on the rigid side. Transfer the placement of the leg's flanges to the sheet with a scribe (inside and outside faces). Drill holes at 1 1/4–inches in from the slot edges, and grind or saw out the remaining material. Place the sheet inside the leg's flanges, and repeat this process on the other set of legs. First, double check to make sure the cart is remaining square. Clamp a bar across the end side of a set of legs, check for parallel, and fasten the sheet to that end. Repeat this procedure on the other end and then fasten the sheet about every sixth inch.

Now place and fasten the end braces to the bottom side the sheet, toeing out and toeing down. Fasten the braces to the sheet and legs.

Stand the cart upright on a flat surface and inspect it for overall fit-up. Adjust the cart's fit with washers to obtain the best compromise possible for overall performance then fasten the rest of the screws. You will have a further opportunity to adjust the cart in one direction once you install the sidewalls and screens.

4. Installing the sheet metal side walls

Lay the cart on its end. Clamp a 6 x 18-inch piece of sheet metal inside of the vertical angles and check the cart for square. The sheet metal is supposed to end up about 1/4-inch below the tops of the vertical angles. Drill holes every six inches (in the centers of the angles) and secure the sheet metal with screws and nuts. Grind off the excess thread inside the vertical angles. Flip the cart over and repeat this process on the opposite wall. Then do the two sidewalls. Remember to check the cart for square before installing the four sidewalls.

5. Making and installing the top angles

Begin by clamping a string tightly between the tops of two diagonal leg angles. Clamp another sting to a third top and stretch it tightly, crossing over the first string, and bringing it down on the fourth angle top. If the two strings fail to touch, your tops don't represent a flat plain. If the strings bend each other more than one string' thickness, they don't represent a flat plain. By raising or lowering one corner, you can establish a flat plain. When your horizontal angles are installed this same method can be used to avoid building a twisted tabletop.

These angles toe down and in. They are fabricated so that they can be removed singly or all at once. This is a convenience during construction and later on when and if the bricks are mortared into a solid surface.

Cut a piece of angle the same length as the overall outside dimension of one long wall (minus the thickness of two flanges). On each end cut one flange back about 1 9/16-inch, and grind the web section of the flange flat.

Slip it between the vertical angles and clamp it to the sheet metal wall with its other flange resting even with the tops of the vertical angles. Then mark the other flange on each end at a 45° angle, using the heel (outside corner) of the vertical angles as your starting point. Make the two cuts and install the angle with self-drilling screws. On all of the top angles the excess screw thread must be left in place. Complete this step on the other three walls.

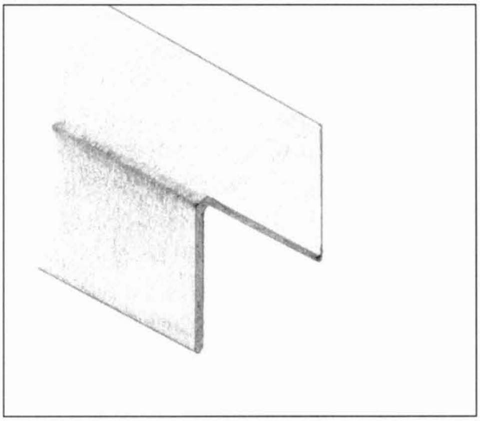


Fig. 6-9 End cut of horizontal top angle; note that the flange with the 45° clearance angle is cut off short of the web, so that after grinding the other leg flat, the horizontal angle will rest even with the top of the vertical angle, without reference to its height. Note also the web radius remaining on the vertical flange. This is the reason that the sheet metal is cut so low.

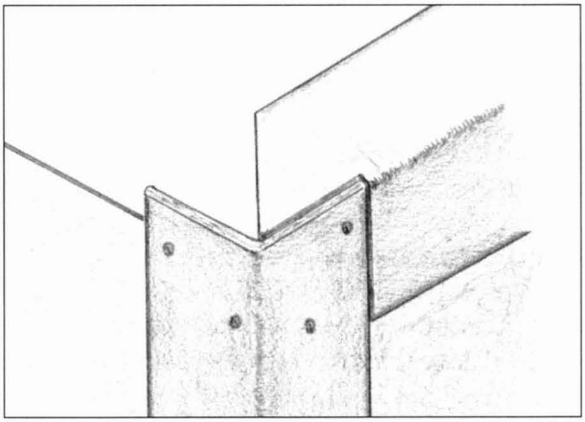


Fig. 6-10 Detail of top corner construction. On the left side of the leg, the sheet metal side wall is kept below the height of the web's radius. The top angle isn't installed on this side yet. The right side of the corner is complete.

6. Mounting the screens

The fuel hoses should be enclosed for protection. By employing flattened expanded metal instead of sheet metal for the cage, the equipment stays visible and open to the air while being isolated from hot metal parts. The screens are placed on the two long sides of the cart. There is no screen on the ends. The coiled hand torch hose is stored on a rack in the open space below the forge. The screen is mounted by trapping it between the flat bars (parts #16 & #17) and the cart's frame with screws and flat washers.

Cut each screen into a rectangle large enough to cover a side face from the bottom of the lower shelf to the toe of the top shelf's bottom angle. But, keep the screens length about 1-inch short of the length measurement so that it will easily fit inside the legs.

Remove one leg from its corner, place an end of the screen under it, and re-install the leg (you may need to ream out the holes in the leg's other flange afterward in order to reinstall the end screws). It will be necessary to drill away parts of the screen where they intersect the screw holes. Repeat the process on the other leg, making sure the screen stays flat against the two shelves.

Drill through the horizontal and vertical angles about every six inches. Position the screw holes next to the screen's metal parts so that the screw caps and nuts will clamp the screens to the angles. Next, turn the cart over and use the grinder to remove all excess thread protruding into the bottom shelf. Then, install the second screen the same way.

7. Final wheel adjustments

To further adjust wheel height use flat washers between the castor plate and the angle face. Two of the wheels swivel and therefore need not be aligned with the cart. Enlarge their holes and twisting them on the faceplate can realign them on the faceplate. Or, the bent flange can be heated (with the forge burner) just above the bend and hammered to tweak the alignment sufficiently to make the cart roll straight.

8. Constructing the burner collar

The collar is placed at the far end of the cart away from the swivel wheels. Measure the width of the top shelf. Place a mark in its center and the same distance from the end wall. Measure the outside diameter of the shower drain thread and ink mark the hole (you can use the paper washer that comes with it). Drill a pilot hole and saw out the hole.

Sand the end of the steel tube clean, flux it, and place it within the drain fixture. Be careful not to put any strain of the fixture. Any stress can force the drain's thread out of round when the parts are heated (don't hammer the parts together). Screw the nut onto the drain. Run silver braze between the two parts. When they cool down, you have a press fit (in effect). Use its four spanner wrench knobs to indicate where to place the four 1/4-20 thumbscrews. Make sure the threaded holes clear the nut. and install the burner collar.

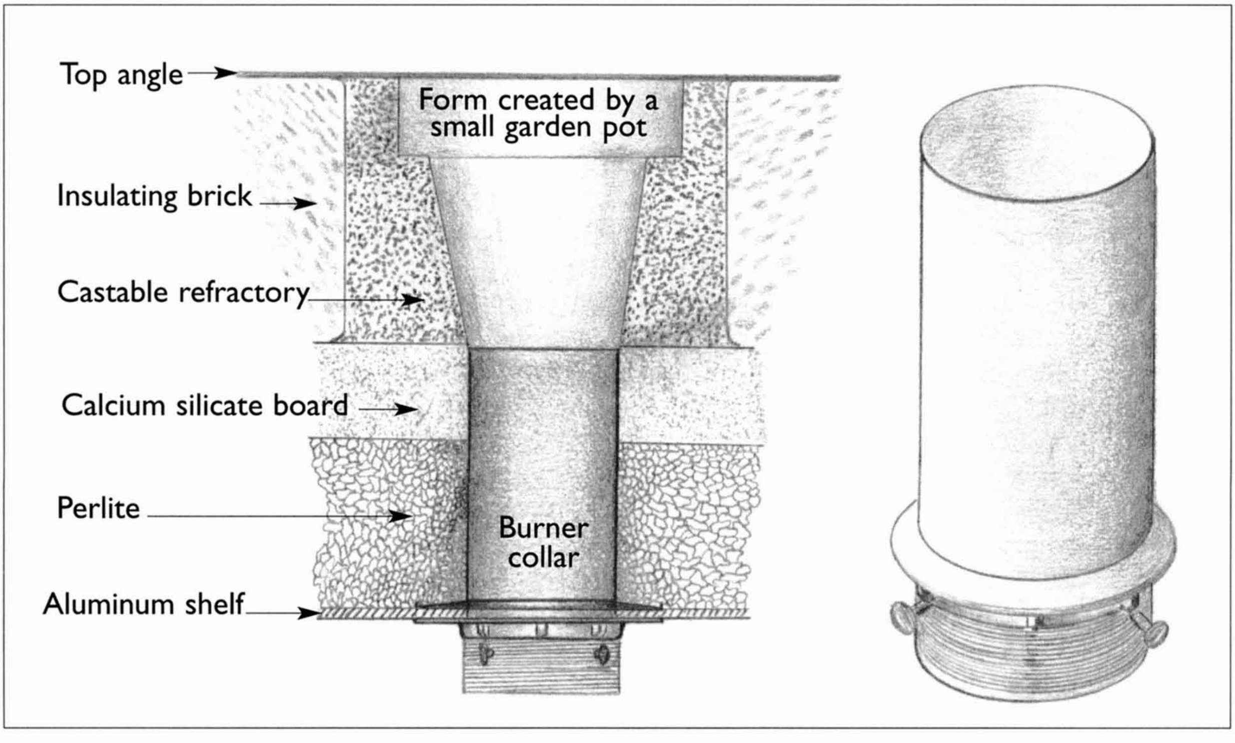


Fig. 6-11. Two views of the burner collar assembly.

9. Insulating the tabletop

This tabletop employs trapped insulating firebrick resting on a foundation of fiberboards. The boards float on a bed of Perlite. The insulating boards are cut and fit closely enough to prevent the granules from rising through the cracks between them so the Perlite will only compact far enough to adjust into a flat plane. The table's top angle irons are toed in, locking the outside ends of the bricks in place. The oversize burner collar extends up through the Perlite and part way through the board. A tapered hole in the brick acts as the burner portal. This allows a variety of burner sizes to be held in a perfect position to be used with the Clamshell Forge and temporary brick forge structures. Because the brick is fragile, it is recommended that a square opening be left in it, and a burner port be poured from castable refractory (see techniques used in Foundry Furnaces, Chapter 9). The port's orifice should be kept 1-inch larger diameter than the O. D. on the nozzle of the largest burner you plan to employ in the cart. It should be tapered. Floral cones can be stuck in the end of the pipe as the inner form. Glass votive candleholders have a good taper, come in various sizes, and often have a built in step. This leaves a convenient ridge for holding a plug. After the refractory has completely hard set the glass is heated, then cold water is poured into it. The pieces are carefully removed when the glass shatters.

Rest the fiber blanket on the bottom shelf of the tabletop and push it against the edge of the top angle to make a depression. Cut the blanket at about 1/2–inch beyond the depression and force it into place against the sidewall. Run this compressible material all the way around the inside of the walls.

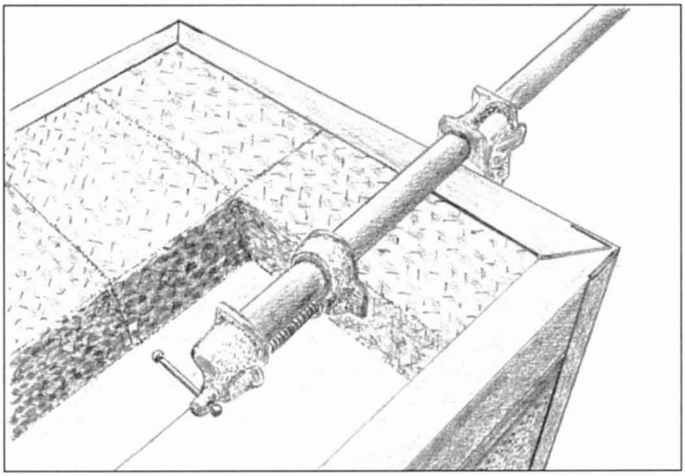


Fig. 6-12 Looking down onto the tabletop as the first brick of the second row is moved into position under the overhanging flange of a top angle. The position of its outside jaw can be adjusted on the pipe, allowing every brick to be slowly forced into position. Under the second row is the off side seam between the two calcium silicate boards.

Fill up the bottom 2-inches of the "trough" with Perlite. Saw the refractory to a length one inch greater than the toe to toe (near edges) measurement of the board top angles. Next remove one end angle. Push the board hard against the closed end and the long sidewall to compress the blanket. You can use a left over piece of sheet metal to "shoe horn" the board down the second end of the blanket then push it down on the burner collar pipe to make an impression for the cut out. Saw on the outside of the impression.

Now use the left over foot of board, along with one of the bricks (as well as the Mullite tiles if any) to show how much more Perlite is needed to top off that layer. Compress the Perlite flat in each area and sprinkle more around (compressing it) until the brick slides under the angle with resistance. In the confined area around the burner collar, use the brick in place of the board and the cut out plug in place of the brick. When you are sure the Perlite layer is flat and the right height, install the first board. Measure the width of the open area and add 1/4–inch. Cut the second board the same length as the first board. Force the second board into place. Replace the end angle.

The bricks are placed facing across the width of the tabletop for most of its length. Push down on the pallet (the proper term for ceramic board used this way) and slip the first brick into a corner. Use the pipe clamp to force it under the lip of the top angles. Place the second brick beside the first using the pipe clamp to pull the first brick clear and then to move the second brick into position. Place the bricks beside one another, working your way across the tabletop until you are close to the burner collar. At this point decide which kind of burner port you will use. If the poured refractory is employed, then place the rest of the brick about two inches away from the collar, forming a square (the brick cuts easily using a hacksaw). If the burner port is cut into the brick, then saw and file each brick to form a tapered opening as you place them.

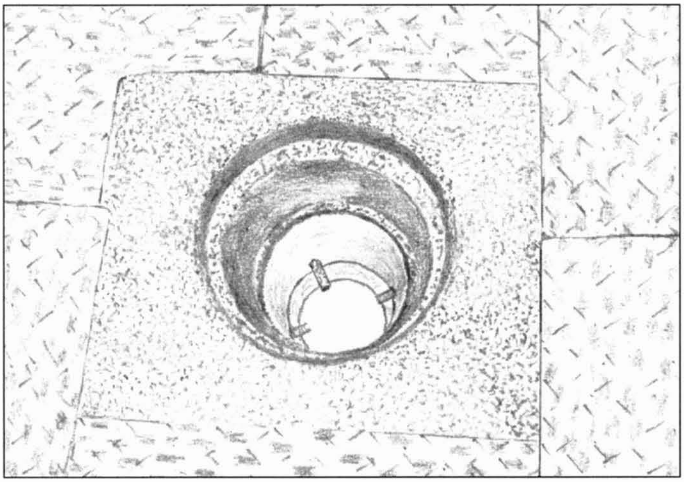


Fig. 6-13 Looking down into the refractory portal, a darkened ring of tapered wall stops at the shoulder left by the glass votive candle form (or small flower pot), then continues narrowing, to end in a thin shoulder surrounding the edge of the steel tube. Near the bottom of the tube three of the thumbscrews protrude above the drain bottom.

The vertical fiber blanket layer acts as a spring, forcing the brick together. But it will eventually take a set. At this point the bricks can be mortared together if desired. To do so, remove the top angle as needed and mortar the bricks a section at a time. Remember the refractory will air set in about twenty minutes. Afterward, the top face should be plastered with the mortar and heat cured.

Accessories

The gas control panel mentioned in Chapter 5 should be mounted on the side screen below the tabletop, attached with flat washers and machine screws from inside the screen. Copper tube can be run from the gas manifold up to the burner. A "tee" fitting, ball valve, and copper tube can connect a permanently located auxiliary hose with a quick coupler to a hand torch or tabletop burner.

Work rack for tube forge

Work should be placed on a crossbar outside the forge. This helps protect the shelf against abuse, and reduces heating time. It is better for the material rack's crossbar to be several inches away from the exhaust, so positioning the bars beyond the edge of the cart makes sense. The rack can also be used to secure the tube forge. Heavy work must be supported by an independent means to avoid overbalancing the cart.

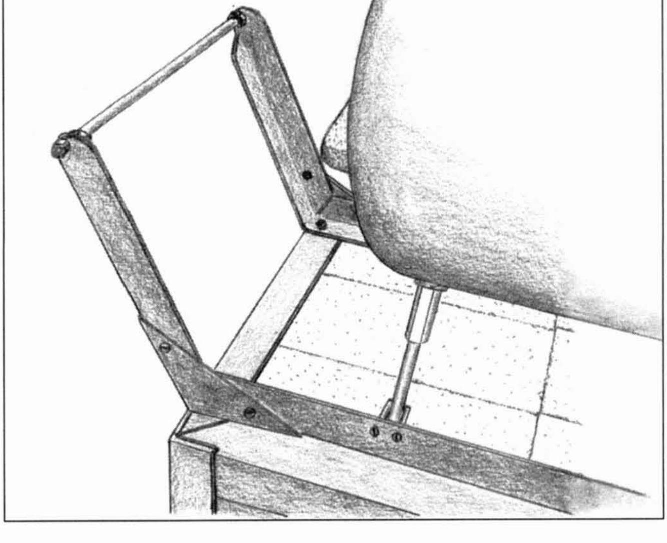
Materials list for rack

(1) Two 1/8 x 1 1/4 x 1 1/4-inch angles, 40-inches long
(2) 1/8 x 3-inch flat bar, 12-inches long
(3) Twelve 1/4-20 x 1/2-inch screws and nuts, plus eight 10-32 x 1 1/2-inch screws
(4) Two pieces of 3/8-inch allthread, 12-inches long, and eight 3/8-inch nuts
(5) Four replacement carriage bolts, 3-inch long
Plastic triangle

Change out the forge legs with four 3-inch long carriage bolts. The two 1 1/4-inch angles are placed toed up and toed in on the forge cart over the desired area. They are centered and squared with a tube forge sitting on them, and then the 1/4-20 screws are used to attach both runners to the cart's top angles. Holes are drilled and tapped for 10-32 x 1-inch screws on both sides of each carriage bolt head, trapping the forge legs on the two angle iron cross pieces.

Next, make 90°marks across the angles where they overhang the forge cart. Mark lines at 30° on both sides of the right angle lines, and cut out the 60° wedges. Heat and bend the excess angle up. Cut four matching wedge shapes out of the 3-inch flat

Fig. 6-14 Perspective view of finished rack. Note the cutaway section showing the allthread inside of the pipe roller.



bar. Place them on the outside of the four joints and pin them in place with the eight 1/4-20 x 1/2-inch screws and nuts.

Level the forge, and use a straight edge to transfer the kiln shelf height to the angle ends. Drill holes for the allthread crossbars even with the kiln shelf, so that the material placed on them ends up just above the shelf and traps them with nuts. Cut the remaining angle neatly back and round off its corners.

Bottle rack

The bottle rack doesn't have to be elaborate. Four angle braces bolted to the sheet metal shelf to trap the tank's bottom ring, and a bungee cord attached to the screens will hold your tank securely, during transport.

Hose rack

Both fuel hoses require hooks to hang from. They can be purchased or made, and can be screwed onto the side screens in the same manner as recommended for the burner control panel. However, if you can find an aluminum angle, say 3 X 5-inch, the hooks can be mounted on it. It can be screwed into the sheet metal pan of the tabletop and provide support for plumbing from the control panel to the hoses. The angle should be placed about one-third the way in, under the tube forge area. The hand burner fuel hose must be removed when using the slack tub. This is why it is fitted with a quick release coupling.

The clamshell forge

The hand burner fuel hose must be removed when using the slack tub. This is why it is fitted with a quick release coupling. The cart constitutes about 3/4 of a clamshell forge's structure. It is also the basis for a variable configuration brick forge/kiln. The clamshell's lid gets bolted onto the forge cart and can be left in place or taken off and stored when not in use. This part is basically a steel shell, and can be recycled out of many things: trashcan lids, steel drum bottoms, or water tank ends.

For this example, a sheet metal barbecue shell is used. Its aluminum exhaust choke is moved inside the lid and screwed closed. Construction methods and tools for a Clamshell lid are covered in Chapter 10. The differences between that model and this one are: (1) Resizing the parts to suit your choice of shell. If the lid is larger than the fiber blanket can accommodate, then the blanket is peeled into layers and they are laid cross-wise to each other before being glued into a solid mass with rigidizer. (2) It is more convenient and efficient to leave movable spaces in bricks sitting on the tabletop for exhaust openings; therefore the lid recesses shown in Chapter 10 are deleted. (3) The lid's handle faces to the side instead of forward and is attached to a rocker arm instead of the lid.

A (drilled) round kiln shelf is recommended as a protective cover for the insulating brick tabletop if no tile is used there. Brick sections are used to form a squat vertical wall with variable openings, and of any desired height. The lid rests upon this wall in the closed position. More than one size lid can be used on the same cart. More than one size of burner can be used with them and with the variable brick forge/kiln.

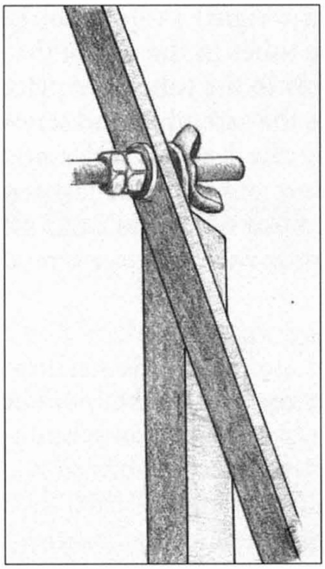


Fig. 15L Detail of rocker arm assembly in raised position. Note the locked double nuts. The brass washer can be moved to any of three places to help vary the amount of drag.

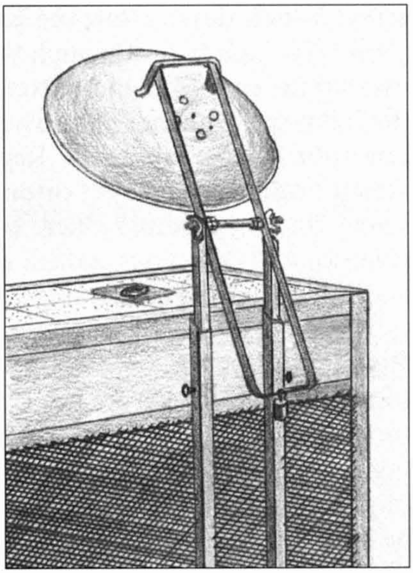


Fig. 16R Clamshell forge with lid in raised position.

The lid's motion coming down is modified with a pressure nut and multiple washers to create drag. This is more than sufficient to hold the lid in any position when a counter-balance, made up of an eyebolt and washers, is hung on one of the rocker arms. The weight can later be changed over to a woven steel line and pulleys operated by a foot pedal.

Materials list

(1) Six feet of 1/8 x 3/4 x 3/4-inch steel angle
(2) Six feet of .065-inch wall, 1-inch square tube
(3) Six feet of 1/8 x 3/4-inch flat bar
(4) Two 1/4-20 x 1 /12-inch thumbscrews
(5) 5/16 x 6-inch allthread, four nuts, two brass flat washers, wing nuts
See Chapter 10 for ceramic materials

Construct the Clamshell lid according to the above discussion. Next, bend the flat bar into a "U" shape. It can be wider or narrower than the length of the lid's handle. You want a loose fit, to allow limited motion for easy leveling. Drill 5/16-inch holes in both legs, 12-inch up from the end bend. Drill a small hole in the bend's center for an eyebolt. Cut two angles 30-inch long; clamp them together and drill matched 5/16-inch holes through the end of one leg in each vertical angle. Cut their other legs back to create end tabs, grind the tab faces smooth and round off their corners; place them on the outside of the "U" and assemble them using parts #5, while adjusting the rocker arms to parallel. They toe toward the cart so that their inside legs can be jammed against the square tube with thumbscrews, and their toes will miss the screw heads that attach the square tubes to the cart.

Gate cut (45° corners) the square tube into two parts long enough to reach from the cart's bottom angle to its top angle. Drill and tap a hole for the 1/4-20 thumbscrew 5-inch down from the top and facing out (a left and a right) in both tubes. Drill 3/16-inch holes through the exposed inner walls of the tubes in the where they overlap the cart's top and bottom angles. Lock the lid assembly in the tubes and place the lid over the burner port. Mark the tube positions, remove the assembly, and screw one tube to the top angle. Replace assembly, lock it above the bottom holes and attach both tubes to the bottom angle. Remove assembly and attach to the last top screw. Replace assembly, drill hole through both arms and both of the lid's handle sides for #10-32 screws. Attach the rocker arms to the lid handle with left over screws and nuts from the cart.

Purchased carts

Most purchased carts are not strong enough to serve as a dependable worktable. The more substantial models are expensive. A standard cart would need partial rebuilding in order to accommodate the features that make it completely serviceable, so you might as well build the cart yourself. If you do choose to buy a "bargain" cart, then be aware that its shortcomings stem from the very thin sheet metal of its construction. This can be improved by a little reinforcement with metal angle braces below the area where the slack tub and propane cylinder will rest on the lower shelf. Braces should be placed diagonally across the bottom of the top shelf, one inside and one outside (crossing in the other direction). Angle should be used to strengthen the legs of the cart too. The angles should be drilled and painted before installation with machine screws and nuts. The leg braces should be employed to trap the expanded metal sides recommended for this cart. They can also extend about six inches higher than the bottom side of the top shelf. Sheet metal walls and angle iron top pieces can than be employed to build a refractory the tabletop featured in this chapter. Such a top would do much to finish strengthening a purchased cart.

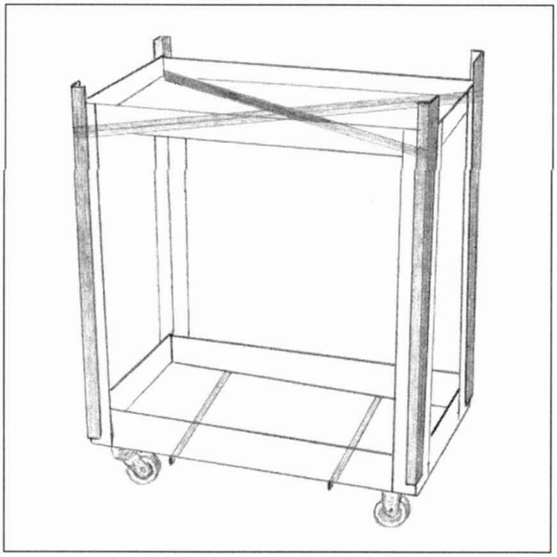


Fig. 6-17 This typical light duty cart is drawn as an outline with the shaded parts showing the added angle bracing as though you could see them through the material of the cart. Because the sheet metal sidewalls and top angles increase both the strength and rigidity of these carts, it is possible to use one, instead of building from scratch, by extending the vertical members all the way to the cart's bottom. The addition of horizontal angle bracing brings the cart up to nominal strength, sufficient for its planned purpose. The additional cost of the cart offsets any savings in metal purchased, but this fabrication scheme can simplify the cart's construction for those in a hurry.

7

The 1-inch Furnace Burner

The 1-inch jet ejector burner is used in 14-inch ID or larger forges or aluminum and bronze hobby furnaces. It has the same high flame temperature and fuel saving characteristics of the smaller burners.

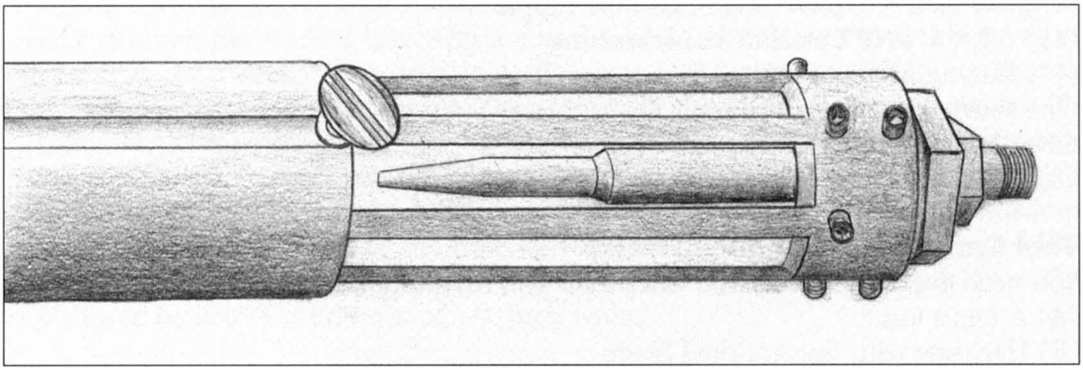


Fig. 7-1 Mixing area and end cap of the 1-inch burner.

You will be referred back to the existing instructions where they apply, but the furnace burner is a more streamlined design than the first two burners. The end cap (part #4) that houses the gas accelerator assembly can be aimed, and the accelerator position is locked with a pressure nut (part #18). The ability to run well two different MIG tip sizes (.035-inch and .040-inch) allows splendid control over a long pressure range. The air intakes and choke sleeve, are fully beveled. Because it is meant for use in furnaces, an ignition opening is included in the choke assembly. If you have already built either of the first two burners, you won't need detailed instructions for many of the tasks in this plan. If you are starting with the burner described here, it will be necessary for you to refer to both of the previous burner chapters, often. The burner's gas accelerator assembly is another silver brazed variation, but in the next chapter there is a simple threaded version.

Materials list

(1A) 1 1/2-inch #316 SS pipe 3-inch long
(1B) 1 1/4-inch sc. # 40 black wall pipe 1 1/4-inch long
(2) 1-inch sc. #40 black wall pipe 13-inches long
(3) 1 1/4-inch black wall pipe 4 1/2-inches long [1]
(4) 3/4 x 1/4-inch NPT bushing (steel preferred)

(5) One #10 1/4-20 x 1/2-inch long thumbscrew, flat washer
(6) 1/8-inch pipe nipple 4or 6-inches long
(7) A .035-inch and a .040-inch MIG welding contact tip 1 1/2-inch long
(8) 1/4 NPT gas rated ball valve
(9) 1/4 x 90° street ell or elbow
(10) 1/4 NPT short nipple (preferably hex, two of them if #9 is a street ell)
(11) 1/8 x 1/4 NPT bell reducer (or threaded bushing)
(12) 9/16-18 LH thread to 1/4 MPT Outlet Bushing
(13) 10-24 x 15/64″ brass threaded wood insert.
(14) 1/8 NPT brass coupling
(15) Six # 10 x 24 x 1/4-inch SS set screws
(16) Six # 8 x 32 x 1/4-inch SS set screws
(17) 1/8-inch X 1-inch long brass pipe nipple
(18) 1/8 x 1/4 NPT steel or brass bushing
(19) Butane fireplace lighter (recommended).
One sheet of #120 sand paper
Silver braze
Gas rated sealant or Teflon tape

Tool list:
You need everything from the Chapter 3 tool list along with the following:
(A) A hand torch
(B) Hacksaw with fine-toothed blade
(C) These drill bit sizes instead of what Chapter t3 calls for: a # 7, a #21, a # 29, two 1/8-inch, a letter "M" or 15/64-inch, 13/32-inch, a 3/8-inch or 5/16 bit (see Step 7, alternate method)
(D) # 10 x 20 starting tap
(E) 10-inch medium coarse square file
(F) Die grinder recommended [2]
(G) 5/32 or 3/16-inch round file (recommended)

Fabrication

Review previous burner chapters in order to complete your understanding of these instructions, and then gather the materials and tools for the burner. Build the burner according to the numbered steps, which along with the parts numbers, are kept as close as possible to their equivalents from earlier chapters.

1. Assembling the burner nozzle, parts # 1A, #1B, and #16

This step is similar to the instructions given in Chapter 3 except for the size of parts. The 1 1/4-inch galvanized pipe (part # 1B) fits loosely over the 1-inch pipe (part # 2). Furthermore, it won't fit within the SS pipe used for the nozzle (part #1A). The solution to both of these problems is to cut the 1 1/8-inch spacer at the weld seam and compress it. Use the hacksaw or a cutoff wheel, then file the opening a little wider (lose about 1/8-inch).

2. Preparing the burner tube, part # 2

Follow the sanding instructions given in step two of Chapter 3 with this burner.

3. Making the choke sleeve, part # 3

In order to make the ignition opening practical, a thumbscrew slot is needed, and the choke sleeve mounted pressure screw is not an option. Cut a piece of 1 1/4-inch pipe 4 1/2-inches long. Scribe a straight line down the length of the pipe. Measure 1/2-inch in from one of the pipe's ends, then center punch the marks. Continue marking and center punching at intervals of 3/16-inch to within 1-inch of the other end. Then, drill 1/8-inch pilot holes. Enlarge the holes with the #21 bit. Grind and file the row of holes into a smooth sided slot. The 1 1/4-inch pipe should slide freely on the 1-inch pipe. Review Chapter 3, Step 3 for more elaborate instructions on accomplishing these tasks. Or, you can drill a 3/16-inch hole at both ends of the proposed slot, cut down the scribed line with a cutoff wheel, change over to a thin grinding wheel and cut a deep "V" groove into the narrow slot, turn the wheel up to right angles and grind a 1/4-inch slot into the groove. As always, finish the ends with a file.

Follow the instructions in Chapter 3 for preparing the back of the burner tube to achieve a sliding fit. After you find a place where the choke sleeve slides freely, use the ink marker to make a line down the length of its slot while it is sitting in this area. Scribe a line from the end of the pipe, down through the middle of the inked line. Leave the ink to remind yourself that this will be the rib that the slot runs over. This rib should be kept a minimum of 1/4-inch wide.

4. Preparing the end cap and pressure nut, parts 2 # 4, 18, &15

The larger bushing (part # 4) should need no preparation. If it does not slip easily into the burner tube (part #2) look for any remains of the internal weld ridge that have not been filed down, or burrs from cutting, that need to be filed away. If the part still will not fit, file the threads until it does. You can mount the part in the drill by using the 1/4 x 1/8-inch bushing and pipe nipple. Then spin the large bushing under a sander. Next, prepare the 1/8 x 1/4 NPT bushing (part # 18) using the instructions in Step 4 of Chapter 4.

5. Installing the thumbscrew, parts #2 & # 5

Place the sleeve on the 1-inch pipe, centered over the ink line, with its back edge 1/4-inch in from the pipe edge (the 1-inch area faces forward of the slot and the 1/2-inch area is back of it). Scribe a cross line in the center of the forward end of its slot for a thumbscrew hole.

Remove the choke sleeve, and center punch the mark. Drill a 1/8-inch pilot hole, and enlarge the hole with the # 21 bit, then thread the hole with a # 10 1/4-20 tap.

Reassemble the choke and tighten the thumbscrew. Use one or two small flat washers with the thumbscrew to create a shoulder. Note the number of excess threads inside the burner tube and remove them. Reassemble your parts (there is a more elaborate explanation of these steps in Chapter 3, Step 5.

6. Placing the aiming screws, parts #2, #4, 15, & 18

Measure the length that the bushing will sit inside the burner tube, and mark two places on the scribed and inked line. One place will be 5/16-inch back from the forward end of the bushing, and the other place will be 1/8-inch from the back edge of the burner tube. Use the choke to help as you scribe the two lines around the pipe's circumference. The six aiming screws used on the forward row must have their faces smoothed (see Chapter 3, Step 1, last paragraph). The three holding setscrews in the back row are left sharp.

Insert the bushing into the end of the burner and trap it with the setscrews. Just run them up to touch it. Do not tighten them down yet. Rotate the bushing until one of the points of its hex head is lined up with the scribed choke sleeve line. Using the angle, scribe the other five lines longitudinally on the burner tube. Center punch all six places on the forward line where it intersects the longitudinal lines, but only center punch every other hole of the back line. The three setscrews that are placed in the back only hold the bushing centered, while the front six screws are used for aiming. Drill the three back holes with a # 29 bit and tap them for # 8-32 setscrews. Drill the six front holes with a # 21 bit and tap them for # 10-32 set screws. Clean up all burrs and install the setscrews. Place the 1-inch bushing into the burner tube, with the setscrews loose gently tighten the three back screws until it is trapped. Hold the tube up to a light source and look down the barrel to see if the bushing is centered. If it is, tighten the screws until they are just touching. Leave the aiming screws loose

7. Making the air openings, part # 2

Lay out the air openings (part # 2)by measuring the length of the threaded portion of the 1 x 1/4 NPT bushing, and make a mark 1/8-inch further distant from the pipe's edge. Slide the choke back to the mark, lock it in position, and scribe a circular line. Now slide the choke forward 2 3/8-inches and scribe a second line. These two lines represent the forward and rear edges of the row of holes. Loosen the set screws just enough to rotate the end cap until the points of its hex head are midway between the six forward sets screws. Scribe new lines forward from the hex points. Make a mark every 3/16-inch starting at the back circular line and ending at the forward circular

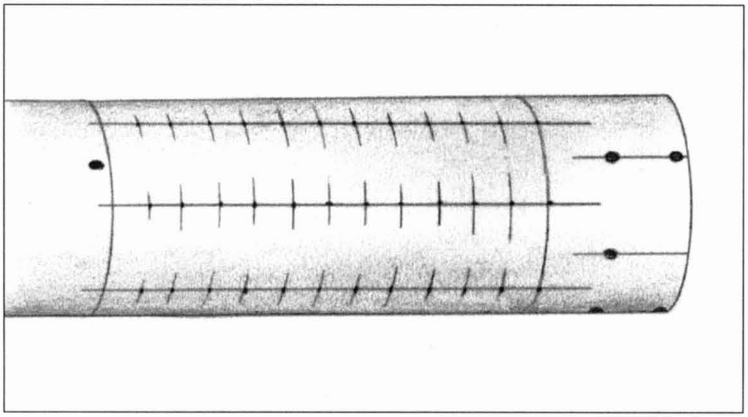


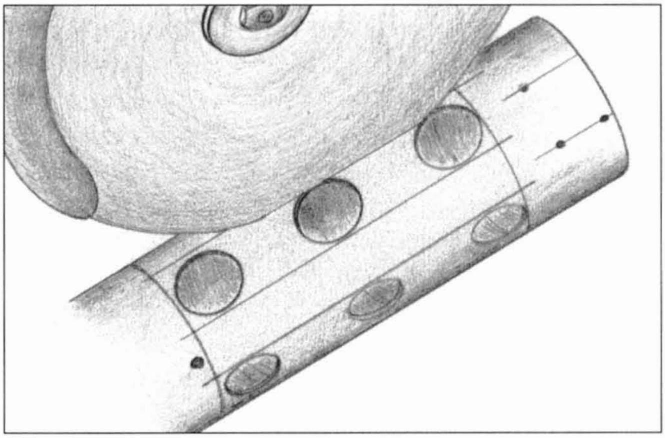
Fig. 7-2 Three of the forward row of set screw holes and two of the back set screw holes, with one line of set screw holes just visible at the tube edge, are placed in the back scribe marks. Forward of these, and centered between them are the scribed and center punched layouts for drilling three of the six air openings. Two complete lines at front and back of these rows have no punch marks, and represent the ends of the openings. A single hole forward is used for the thumbscrew. Fig. 3-7 demonstrates how the choke sleeve is first used to help lay out a drilling pattern.

line. Use the choke to help scribe the new lines around the pipe's circumference. Remove the choke sleeve and thumbscrew. Center punch the intersections of all the lines except for the forward and back lines at the air opening's edges (the two original lines). Scribe longitudinal lines 3/16-inch on either side of the longitudinal centerlines. These two outer lines and the forward line make the edges of the air openings.

Drill a 1/8-inch pilot hole in each punch-mark, and enlarge all the holes to 1/4-inch. Then, drill them out to 3/8-inch. Grind and file the row of holes into slots, then file the forward edges of the slots into squares.

Or, drill 5/16-inch holes at both end punch-marks and in a center punch-mark. Then, use the cutoff wheel, placed just inside the outer longitudinal lines to cut between (but not into) the forward and back holes. Do not try to cut all the way to the slot ends. Hammer out the two weakened "slugs" of left over material within the slots. File the forward ends of the slots into squares.

Fig. 7-3 The cutoff wheel on a 4 1/2-inch angle grinder has penetrated the first and middle 5/16-inch holes, and will be taken to the middle of the last hole. Note that the back side of the blade is even with the scribed line. Next, the blade will cut away the inside of the other line. Care must be taken not to cut beyond the centers of the end holes.



Slip the 1/8-inch pipe nipple into the locking nut and screw them into the end cap. To check the accelerator's aim, turn the burner and view the pipe through each of the air slots. Again, hold the burner up towards a bright light source and look at the pipe end through the open front.

With the back setscrews just touching, aim the ejector assembly by manipulating the forward ring of setscrews until the contact tip is axially true with the burner tube. Now, tighten down all eight setscrews to a snug fit only; don't over-tighten them. Loosen the end cap's locking nut, and remove the pipe nipple. Then, clamp the burner in a vice, in the vertical position. File the backs of the air intakes square and even with the end of the bushing. In order to maintain a good view of the work, you should rotate the burner for each opening.

Now, tilt the burner back at an angle in the vice and bevel the back of the intake with the square file and grinder. Bevel all six openings this way. Each bevel's knife-edge meets the circular edge of the bushing. The squared and beveled ends of the air openings promote laminar flow. Reverse the burner in the vice and bevel the inside of the air intake's forward edges in the same manner that you just used to make outside bevels on the rear edges. The forward bevel's knife-edge meets the inside of the choke sleeve, so that the two beveled surfaces form a funnel when the choke is fully open.

Optional sealing slots

These slots may be needed to allow the choke to slide back far enough to seal the burner after shutdown if it is used in a forge. If it is only used as a hand torch, it is better left unable to completely close. If it is used in a furnace, the choke should usually be left open at shutdown. To make the slots, slide the choke sleeve up against the forward setscrews and mark their positions on the flare's edge. Center punch and drill the forward end of the slots. Grind out the slots with the thin grinder blade. Check the burner to see if the choke sleeve completely closes. Grind any needed changes in the slots, in order to make the sliding action smooth.

Recommended ignition port

When the burner is installed in a furnace, it can be ignited with a butane lighter inserted in an air opening, but to light with a match requires an ignition port. The choke sleeve on this burner has been deliberately lengthened in order to accommodate such an ignition opening. Scribe a mark on the opposite side of the choke sleeve from the thumbscrew, scribe a cross line 1-inch from the forward edge of the sleeve, and center punch. Then, move the sleeve open 1/2-inch beyond the forward edge of the intake openings, and lock it in place with the thumbscrew. Drill 3/8-inch holes through both parts with the burner held in this position. File away all burrs from both parts, inside and out. When the choke is completely closed the two holes are separated, sealing the burner. When the choke sleeve slides forward enough for the holes to match up, the choke is also opened to a place for ignition. Once the choke is moved forward, the burner tube hole is again covered, so as to create minimal turbulence. A small recess filed in one side of the slot can indicate where proper alignment is without the need to look.

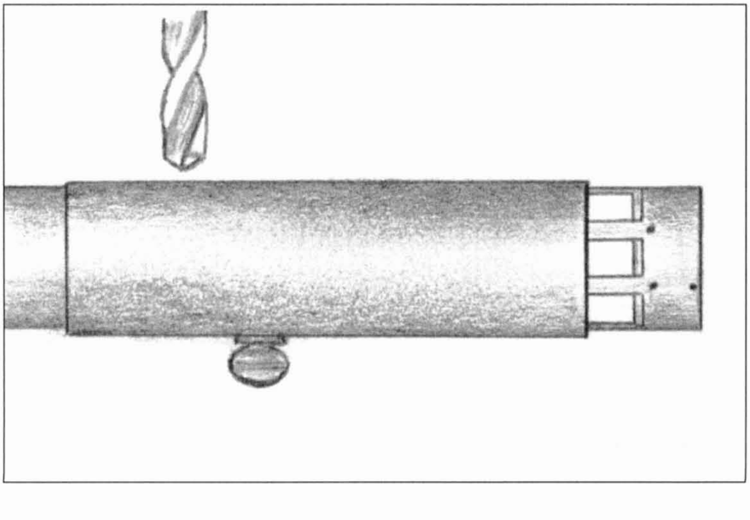


Fig. 7-4 A 3/8-inch drill is poised make the matching holes through both the locked choke sleeve and the burner tube.

9. Making the gas accelerator assembly, parts #6, # 7, & #13

This fourth accelerator design is not superior to previous methods. However, it uses a different brass fitting and is easier to silver braze. Make a pocket to hold the brass wood insert in one end of the 1/8-inch pipe nipple (part #6) with a 15/6-inch or "M" size drill bit. Use the drill and tapping fixture from Chapter 3 (parts #14 & #17). Follow the drilling instructions given there including the depth of the markings. Do not cut off the threaded portion of the pocket.

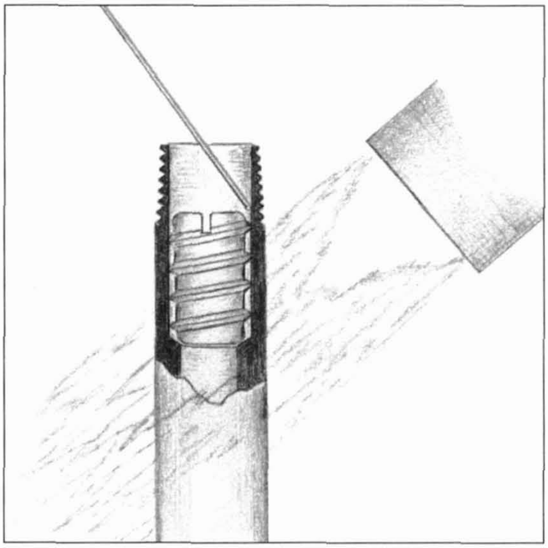


Fig. 7-5 A cutaway view of the recessed pocket in the gas tube (1/8-inch pipe nipple) containing a 10-24 x 15/64 brass threaded wood insert, which is being silver brazed. See Fig. 3-11, left side, which shows how the gas tube would be held in the drilling and tapping fixture to make the recess or "pocket" for the insert. You have only to imagine the brazed insert in that same fixture afterward, Drilled with a #7 bit in a manner similar to the part in Fig. 3-9, then being threaded with the 1/4-28 tap, again using the fixture in the same manner described in that section, and finally having the exterior threaded portion cut off, as in Fig. 3-11, right side.

Next, burnish the outside threads of the wood insert with a wire brush and spread flux on them, then place the insert into the bottom of the pocket. Slip the 1/8-inch pipe into the locking nut and end cap, then lightly clamp the caps hexagonal flats in the locking piers, so the parts can be set upright for brazing. Silver braze the parts together (the large outside thread makes a natural channel for the solder to run down and fill.)

After removing the 1/8" pipe from the locking nut, screw it back into the drill and tapping fixture. Change the 1/8-inch x 1inch pipe nipple with the enlarged hole for the second nipple, and drill a #7 size hole through the insert using the fixture as a guide.

Thread the insert with a 1/4-28 tap. You will find very detailed instructions for doing so in Chapter 3's accelerator section. Now, cut off the outside thread and excess brass from the gas tube's face, and then chase the 1/4-28 thread with the tap. Clean

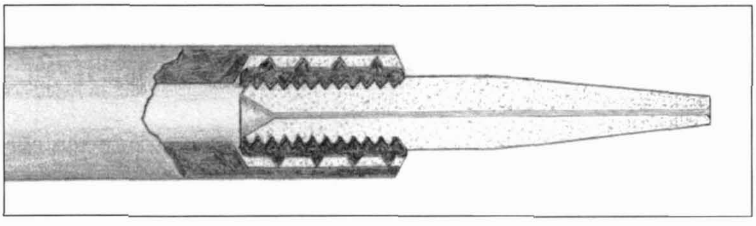


Fig. 7-6 A cutaway view of the finished accelerator showing the brass threaded wood insert brazed in place and the MIG tip screwed into position.

the excess flux out of the pipe nipple with a round file, and blow out any metal shavings again.

Use Teflon tape and screw the tip into the 1/8-inch pipe. Place the accelerator on a straight edge and take comparative measurements. Use pliers to gently straighten the contact tip until you feel satisfied with the result.

If you had to buy a standard tip, mount the whole accelerator assembly in the drill, and spin it under a grinder or file to shape the tip to a taper. Leave about 3/32-inch of blunt end in order to avoid creating a sharp (weak) edge at the orifice.

10. Assembling the valve and hose fittings

See the directions in Chapters 3 and 4.

Burner Ignition

Loosen the locking nut and rotate the burner until the thumbscrew is at two o'clock and the ignition port at eight o'clock (or thumbscrew at ten and port at four), then lock the burner in this position. Unlock the thumbscrew and slide the choke sleeve forward until the holes line up in the ignition port. Strike a match or light the fireplace burner and move the flame up to the opening. Turn the gas on and increase pressure until the internal flame is blown forward into the burner nozzle, then open the choke up to achieve a neutral flame. After the burner warms up, open the choke to wherever desired.

Tuning

You should take great pains to insure that the accelerator is centered in this burner, for the best performance. The accelerator's tip should be even with the forward ends of the air intakes or no more than 3/8-inch away. The nozzle overhang is about 1 3/4-inches. This burner is less sensitive to choke position when cold than the two previous sizes. Otherwise, follow the tuning instructions in Chapter 3. The smaller MIG tip gives peak performance in the lower pressure range, enhancing fuel economy. The larger tip allows greater maximum gas flow for higher overall heating capability. It is necessary to practice with both tips to complete your understanding of the burner.

Maintenance

If used in a forge it is normal to have these burners facing down. In that case the burner choke must be closed at shutdown. However, when they are used horizontally, near the bottom of a metal melting furnace, the choke should usually be left full open after shutdown in order to draw cool air through the burner. Chimney effects remain the same, but the burner's position makes them an advantage instead of a threat. Otherwise, maintenance and safety on this burner is identical with the procedures in Chapter 4.

8

1 1/4-inch Furnace and Kiln Burner

The 1 1/4-inch jet ejector burner is intended for use in ceramic kilns, or in glass and metal furnaces. However, it is also valuable as an external heating source for assemblies or parts too large to fit within forges. There is an ignition port installed just forward of the air intakes. It is identical to the port on the one-inch furnace burner. Do not depart from this burner's design parameters because the larger burners have a narrower range of stability than smaller versions. The gas accelerator is a completely different design than previous burners have used. It does not require silver brazing or brass parts, but the sc. #80 1/8-inch pipe nipples needed for its gas tube are not easy to find locally. The other accelerators will adapt well to this burner.

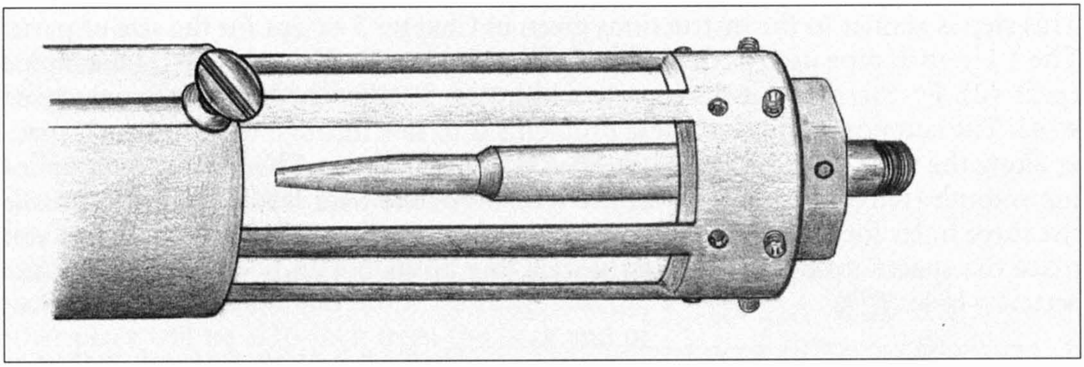


Fig. 8-1 Mixing area and end cap of the 1 1/4-inch burner.

Materials list

(1A) 2-inch ID SS tube, 3-inch long (heavy wall strongly recommended) [1]
(1B) 1 1/2-inch sc.#80 black wall pipe, 1-inch long
(2) 1 1/4-inch sc. #40 black wall pipe 16-inches long [2]
(3) 1 1/2-inch sc. #40 galvanized pipe 4 1/2-inches long
(4) 1 x 1/8 NPT bushing
(5) One 1/4-20 x 1/2-inch long thumb screw, and 1/4-inch flat washer
(6) 1/8-inch pipe sc. #80 pipe nipple 4 or 6-inches long [3]
(7) Two 1 1/2-inch long MIG contact tips for .045-inch and .052-inch wire [4]
(8) 1/4-NPT gas rated ball valve
(9) 1/4 x 90° street ell or elbow
(10) 1/4-NPT short nipple (preferably hex)
(11) 1/8 NPT x 1/4 NPT bell reducer

(12) 9/16-18 LH thread to 1/4 MPT outlet bushing or 3/8 flared fitting
(13) Can of tappping oil
(14) 1/8 NPT coupling
(15) Fourteen #10 x 32 x 1/4-inch SS set screws
(16) 1/8-inch X 1-inch long pipe nipple

Tool list:
Same as Chapter 7, but without the burner, hacksaw, #29 drill bit, a 8-32 tap.
Tapping fixture from Chapter 3 recommended
Size "Z" letter drill bit or 27/64-inch bit (not 13/32-inch this time)
1/8-inch NPT die, 1/8-inch #80 pipe, but not pipe nipples

Fabrication:
Review previous burner chapters in order to complete your understanding of these instructions, and then gather the materials and tools for the burner. Build the burner according to the numbered steps, which along with the parts numbers, are kept as close as possible to their equivalents from earlier chapters.

1. Assembling the burner nozzle, parts #1A, #1B, and #15

This step is similar to the instructions given in Chapter 3 except for the size of parts. The 1 1/2-inch pipe used as the spacer (part #1B) doesn't fit over the 1 1/4-inch pipe (part #2). Furthermore, it fits loosely within the SS pipe used for the nozzle (part #1A). The solution to both of these problems is to saw through the 1 1/2-inch spacer along the weld seam and spring it open. Use the hacksaw. Then, file the cut opening smooth (remember to file away the remains of the weld seam). When you make the three holes for setscrews, only drill and thread the nozzle (part #1A). When you place the spacer inside of the outer nozzle line up its cut ends well away from the setscrew holes.

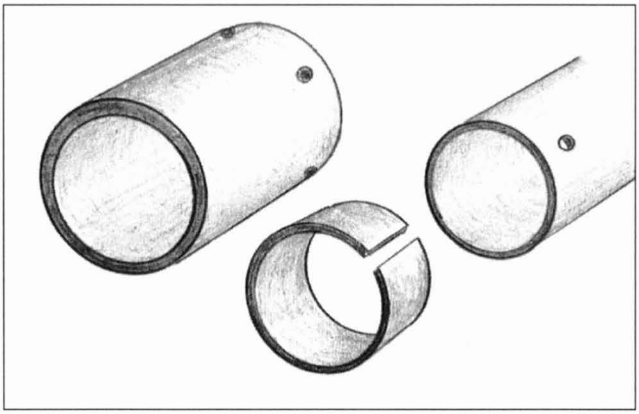


Fig. 8-2 At left, the fourth and last set screw hole shows in the nozzle's center. On the right its matching threaded hole through the burner tube. The split spacer is in the center.

After the burner is constructed and tuned, scribe a line on the nozzle between the spacer's cut ends in order to drill and tap a hole through all three parts. The fourth setscrew blocks airflow through the opening, and locks the nozzle in place. Screw the first three setscrews into the nozzle. Leave them just touching the spacer. It may be necessary to sand the spacer in order to fit the nozzle on it. But, sand off the black varnish in any case.

2. Preparing the burner tube, part #2

Follow the directions as laid out in step two of Chapter 3 for installing the nozzle and preparing the burner tube.

3. Making the choke, parts #2 & #3

Flaring must not be used on this sleeve. Flaring sacrifices some control in return for greater airflow. In this burner and larger sizes airflow needs to be reduced somewhat, rather than encouraged. Fine-tuning which the flare interferes with, is critical to performance in the larger burner sizes. Cut a piece of 1 1/2-inch black wall pipe 4 1/2-inches long, then follow the fabrication instructions in Chapter 3.

4. Preparing the end cap, parts #4, & #15

One of the flats on the 1 1/4 x 1/8-inch bushing is drilled and tapped for a #10-32 set screw. Then the center hole is drilled out with a size "Z" letter drill. A larger version of the Chapter 7 end cap can be substituted.

5. Installing the thumbscrew, parts #2 & # 5

Follow the directions in Chapter 7, Step 5.

6. Placing the aiming screws, parts #2, #4, & #15

Measure the length that the bushing will sit inside the burner tube, and mark two places on the scribed and inked line. One place will be 5/16-inch back from the forward end of the bushing, and the other place will be 3/16-inch from the back end of the burner tube. Use the choke to help as you scribe the two lines around the pipe's circumference.

Insert the bushing into the end of the burner and trap it with the setscrews. Just run them up to touch it. Do not tighten them down yet. Rotate the bushing until one of the points of its hex head is lined up with the scribed choke sleeve line. Using the angle, scribe the other five lines longitudinally on the burner tube. Center punch all six places on both circular lines where they intersect the longitudinal lines, and center punch all twelve places. Every setscrew is used for aiming with this cap. Drill the holes with a # 21 bit and tap them for # 10 x 32 set screws. Clean up all burrs and install the setscrews.

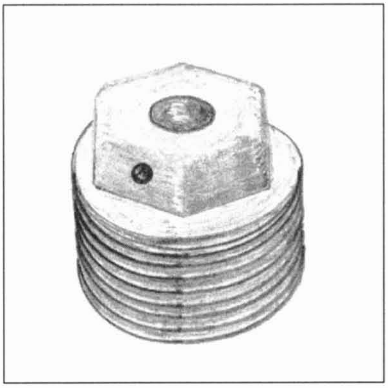


Fig. 8-3 A #10-32 set screw sits in one of the 1 1/4 x 1/8 NPT bushing's faces, intersecting the size "Z" (or 27/64-inch) hole.

7. Making the air openings, part # 2

Follow the directions in Chapter 7, Step 7, but lay out and cut the openings 7/16-inch wide. If you use the cutoff wheel, this would mean cutting on the lines instead of inside them.

8. Optional closing slots

Follow the directions in Chapter 7, Step 8.

9. Recommended ignition port

Follow the directions in Chapter 7, Step

10. Making the gas accelerator assembly, parts #6, and #7

If you acquired a starting tap, rather than the more usual plug tap, thread can be run in the gas tube, by careful hand tapping, without using the Chapter 3 tapping fixture. In this case, cut off the threaded portion of one end of the 1/8-inch pipe nipple and proceed.

Otherwise, the 1/4-28 thread for the MIG tip (part #7) is tapped directly into the 4 or 6-inch pipe nipple (part #6). Begin by screwing the short nipple (part #16) into the 1/8-inch coupling (part # 14) to make a tapping fixture. Gently clamp the locking pliers to the coupling to hold the fixture for tapping. Measure the thread on one end of the pipe nipple, add 3/8-inch to it and write down the combined measurements. Screw that same end of the nipple into the other side of the fixture. Push the 1/4-28 tap into the fixture until it touches the pipe nipple. Mark the distance of the written measurement on the body of the tap. Forward of the mark, wrap electrical tape around the tap so that its back edge is even with the mark. Use enough tape to reduce the free-play between the tap and the inside of the short nipple to a minimum, but still allowing the two parts to turn freely. This should maximize the accuracy of the work. Thread the tap down to the back edge of the tape, using the methods previously described in Chapter 3. However, in this case, do use tapping fluid generously.

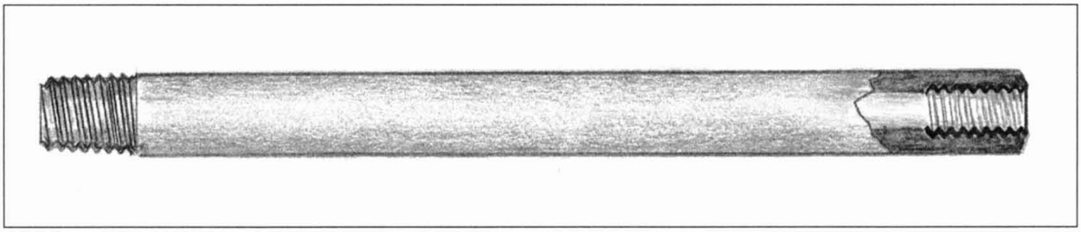


Fig. 8-4 Thread is tapped directly into the sc. #80 pipe.

Unscrew the nipple, and cut off the exterior threaded portion of its end. Clean out the newly constructed gas tube and mount the MIG tip as shown in Chapter 3. Save the tapping fixture for making other accelerator gas tubes. Spin the cutoff end under a file to create a bevel.

11. Assembling the valve and hose fittings

See the directions in Chapters 3 and 4.

Burner Ignition

Follow the instructions in Chapter 7.

Tuning

You should practice igniting and tuning the burner until you are thoroughly familiar with it before installation. This burner is less forgiving than any of the previous models. The accelerator's tip should be even with the forward ends of the air intakes or anywhere up to 3/8-inch back of them. The nozzle overhang is about 2-inches, and the minimum gas pressure is twelve PSI. Otherwise, follow the tuning instructions in chapter three. Remember, that there are two different tips to become familiar with.

9

Foundry Furnaces

This chapter details the construction of a small jeweler's furnace. It will be followed by some general technical discussion. However, founding is a subject that would require many books to cover. There are texts available on casting, and most of them have tips on furnace design. The 1958 Naval Foundry Manual is probably the single

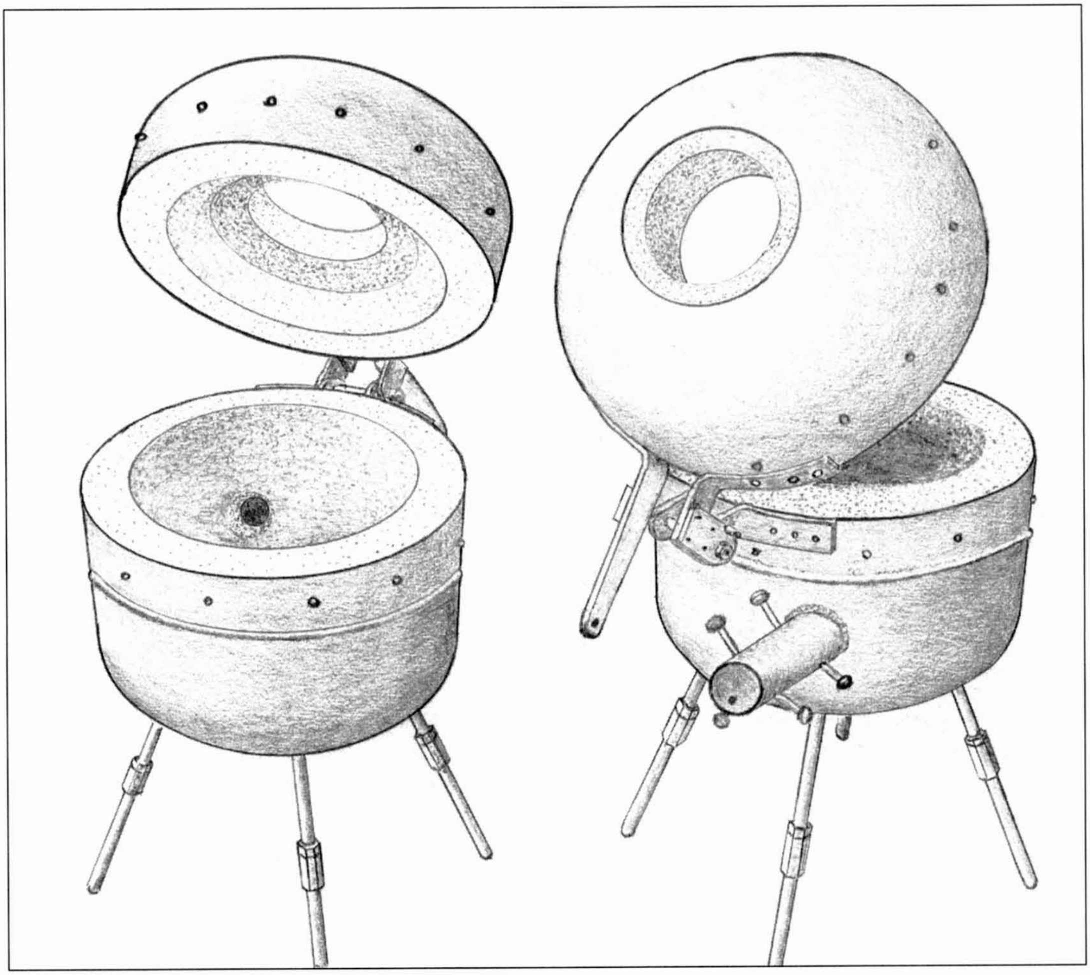


Fig. 9-1 Two views of the jeweler's furnace. This is the fastener assembled version, and features a lowered lip on its lid.

most useful book of this kind. There are also numerous web sites devoted to hobby casting and furnace building (see Resources).

Safety demands that even the smallest furnace employ a gantry or a hinge to suspend the furnace lid while handling crucibles. Its refractory reaches yellow heat. This puts you at risk when you lift off the furnace top, and puts the lid at risk when you set it down on a "cold" surface. If you are making multiple pours, the furnace top must be handled repeatedly. Safety concerns are reduced with a suspension system.

"Bean can" forges and then coffee can furnaces made their debut on the Net about five years ago. The miniature forges began as toys although they were useful for heat treating hand tools. At first they used propane or MAPP gas plumbing torches, and then smaller practical burners were designed. At about this point, someone decided to make a coffee can foundry furnace. These furnaces are sized for jewelers. A very nice one was designed for casting model railroad parts. The term comes from the three pound coffee cans employed as their shells, but the builder should not feel limited to tin cans in this regard. The economies of scale are not very important for the average jeweler's furnace because, as the sizes diminish, so do the fuel savings between one size and another. Unless you contemplate melting platinum (which would require a special furnace for other reasons) there is small advantage to building a miniature furnace. On the other hand, being able to melt larger amounts for the occasional small sculpture or base plate, not to mention the ability to fit the mold itself into the furnace for glass sculptures, will more than repay a dollar in wasted gas with smaller crucible pours. For metal artists, the small furnace shown here should be considered as optimal. It is designed to accommodate the 3/4-inch burner, but can be run with the 1/2-inch. For larger furnaces, water heaters and air tanks can be combined with the following construction techniques to scale up to any desired size.

Building the jeweler's furnace

This furnace was inspired by watching the exhaust form a little donut of yellow fire about four-inches above the exit of Dan Brewer's small hobby furnace. The sight was a sure sign that his furnace had perfect draw; the flame only came from impurities in the scrap he was melting. The fuel gasses themselves were completely spent. A 3/4-inch burner, at 8 PSI, melts 7 # of aluminum in 20 minutes from a cold start, with fifteen minute melts when hot.

Excellent performance and ease of construction tips the scales heavily in its favor. You will be referred to some fabrication steps and drawings from Chapter 5 where they apply. It uses high temperature castable refractory instead of RFC. There is an insulating outer layer of refractory even though this furnace is small. This is accomplished by mixing the hard face refractory with crushed insulating firebrick or Perlite instead of purchasing a second bag of insulating refractory. An IR reflector is used as a finish coating. When combined with the 3/4-inch burner from Chapter 4, it is more than sufficient to rapidly heat a 4 x 6-inch or smaller crucible of aluminum. The furnace is built with a drain hole and rests within a sand filled mop bucket in case of crucible failure. An ingot mold can be centered below the hole to recover precious metals.

Please read through all the instructions, including alternate fabrication techniques, and material choices before deciding on a construction plan. There are welded and fastener assembled versions given. There are also two different lid versions, one of which has part of the vertical wall incorporated into it. Either lid can be used with either assembly version.

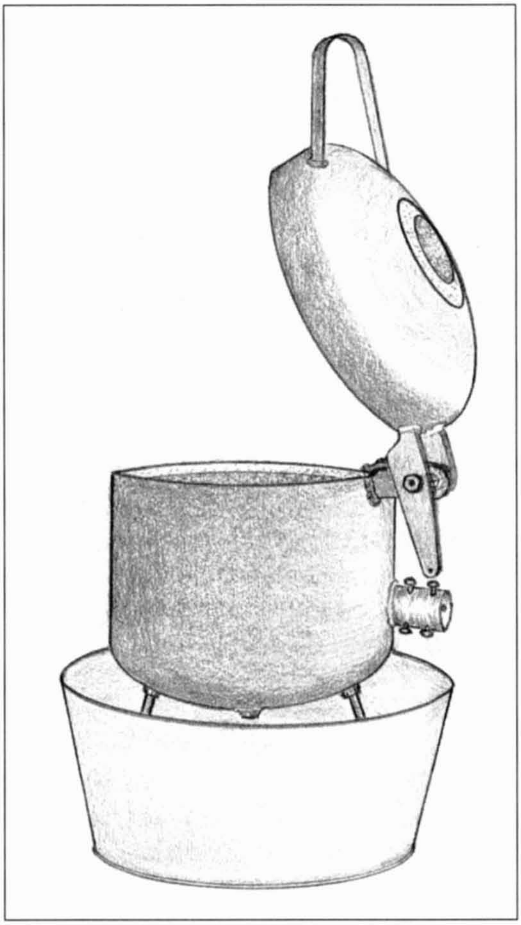


Fig. 9-2 A welded furnace version, with a standard lid. It is sitting in sand and resting in a mop bucket. It is shown with a flat bar handle.

Materials list:

(1) An unused five-gallon propane bottle
(2) A 1 1/2-inch ID pipe, 4 3/8-inch long
(3) One large steel flat washer, with a 3/4-inch hole, and at least 1 1/2-inch OD
(4) Six 1/4 x 20 thumbscrews 1-inch long.
(5) One 55# sack of 3000° F castable facing refractory [1]
(8) One spray can of heat resistant paint
(9) One pint of ITC # 100 infrared reflective coating
(10) 3/4-inch jet ejector burner [2]
(11) Fuel gas regulator with gauge, propane hose with quick disconnect, ball valve,
and a fully charged propane bottle for use with burner (see Resources)
(12) Ink marker
(13) Four #10-32 screws, 3/4-inch long, nuts, one dozen flat washers
(14) Eight 1/2 x 8-inch lengths of allthread rod and coupling nuts
(15) 3/8 x 4-inch length of allthread rod, a coupling nut, two plain nuts
(16) Twelve1/2-inch plain nuts and four locking washers
(17) 1/8-inch x 1/2-inch steel flat bar 5-foot long
(18) 1-inch pipe plug
(19) Box of #10 self-drilling sheet metal screws, 1-inch long
(20) One box of salt, 5-inch diameter
(21) Piece of 1-inch diameter candle
(22) #60-grit sandpaper and dust mask
(23) Two rolls of electrical tape or a roll of duct tape
(24) 1/4 x 1/2-inch flat bar, 18-inches long
(25) Four 1/8 x 1-inch flat bars, 1-foot long for fastener assembled version or two 1/4 x 1 1/2-inch flat bars 1-foot long for welded version

(26) 3/16-inch round bar 3-inch long, six inches of light chain
(27) Vaseline, or petroleum jelly
(28) Bag of Perlite (about one-half of a cubic foot)

Tool list:
(A) Electric hand drill, along with a 1/8-inch drill bit, a 5/16-inch bit, a # 7 bit, a # 21, a 3/16-inch, a 3/8-inch drill bit, two11/64-inch drill bits, a 2-inch hole saw, see Step 3, metal cutting countersink [3]
(B) 4 1/2-inch right angle grinder, with thin cutting discs, a #60-grit flap disc, two #24-grit flap discs
(C) Saber saw with steel cutting blades [4]
(D) Welding machine helpful
(E) 6-foot tape measure, 12-inch dividers, 12-inch square, ink marker, scribe.
(F) Locking pliers or Vise-Grips
(G) Two disposable 1-inch paintbrushes
(H) Small center punch or prick punch
(I) Safety glasses
(J) Plastic level
(K) Scribe
(L) 1/2 x 1/2-inch angle about 6-inches long
(M) 10-inch half round file

1. Laying out the tank ends

Prepare the tank using the instructions in Chapter 5, Step 1. With its foot-ring sitting upon a flat surface, mark a line all the way around the tank's periphery about 1-inch up from its curve. Use a block of wood to support the ink marker at the right height. Center punch the line to preserve it during the "cooking" and sanding of the paint. This is for the standard lid. Mark the line at about 4-inch up from its curve to get the lowered lid version shown in the opening drawing. The standard lid is easiest to build, while the lowered lid gives maximum access to small crucibles.

Now, follow the instructions in Chapter 5, Steps 2 through 4, in order to lay out an 8-inch circle on the other end. But, instead of laying out a six-inch long flat line, use the dividers to find and scribe four equidistant places on the circle and punch mark them for later drilling. Then, fill the tank with water up to the beginning of the curved end, and screw in the 1-inch pipe plug.

2. Cutting the exhaust opening

Prop up the tank on this end, and stabilize it to keep it from shifting during grinding. Follow the instructions in Chapter 5, Step 5, to find the other end's center and punch mark it. Remove the foot ring, and clean the weld scars. Use the dividers to layout a 6-inch circle. Use a thin grinding disk or a metal cutoff disk at an angle to cut just within the circular line. Drain out the water, turn the tank over, remove the plug, and drill the four 3/8-inch holes on that end.

3. Drilling out the opening for the burner collar

Make a mark directly over one of the four holes on the end of the cylinder and place the tank on the threaded 1-inch opening according to the drilling instructions given in Chapter 5, Step 7. Measure up 4 1/2–inches from the supporting surface and center punch. Drill the burner opening out

4. Preparing the tank

At this point, follow the directions in Chapter 5, Step 6, for cooking a used tank if you didn't buy a new one (the 6-inch exhaust hole is positioned at the top). Then, use the flap disc to clean the paint off the furnace shell's exterior (it's no longer a propane tank). Next, sand the hole smooth by using the flap disk turned up at a steep angle or use a half round file if it makes you feel more comfortable.

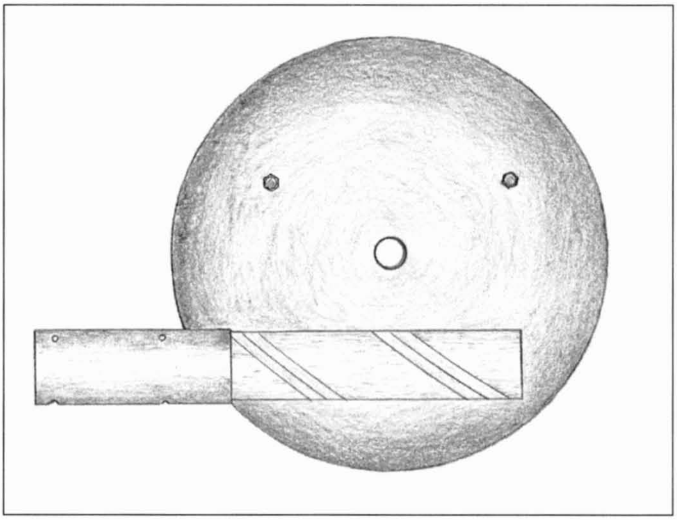
5. Cutting the tank in two

Prop the shell on its side using wood or angle iron to keep it from rolling. Use a metal cutting disk to cut along the punch marked seam. You can first use paper, or a flexible plastic ruler to ink a solid line to follow if desired. Afterward, smooth the cut edges with the flap disc. There is an alternate cutting method given in Chapter 11, Step 3.

6. Constructing and mounting the burner collar

The 1 1/2 x 3-inch pipe is now going to be laid out, for use as the burner collar. Unlike the forge in Chapter 5, burners are positioned horizontally in furnaces. This requires better support from the thumbscrews, so there will be six screws used instead of three. The burner sits at an angle to the curve of the forge shell so that the flame can be aimed between the furnace wall and the crucible. This provides a swirling path for it between the crucible and the furnace wall, without directly impinging on either of them for the first few inches. Allowing the heat of the flame

Fig. 9-3 The view as seen looking down into the bottom section of furnace shell. The center hole left after the plug is removed will become the emergency drain hole. In the left and right hand areas, two of the four inside nuts are visible. The other two nuts are hidden below the cardboard tube, which is projecting into the shell from the inner face of the burner collar. The space between the edge of the cardboard tube and the curve of the shell should measure 2-inches. This assures the correct aim for the flame path once a 2-inch refractory lining is poured



to spread out before touching does much to preserve both of them.

Save the cardboard tube from a roll of paper towels. Remove the six thumbscrews, and file the inside of the pipe smooth. Push the tube into the pipe, slit it for a few inches if it won't fit otherwise, to line up the burner centered and axially true in the pipe. The tube becomes your "site" for lining up the collar's aim. It should clear the inside of the shell by 2-inches at the furthest point in the shell wall's curve. File the sides of the collar's hole to allow the pipe to swing far enough for proper aiming of the flame path.

If your thumbscrew holes are placed in a vertical and horizontal pattern, one of the six screws might not clear the shell. So, they are positioned at seven, eleven, and three o-clock. Make a single weld tack on the top of the pipe, check the horizontal position, and make a bottom tack. Check the aim, and then tack the two sides. Weld the collar on permanently. The burner can be repositioned using the thumbscrews if your work is a little off.

7. Attaching the legs, parts #14

Run a nut on each of four allthread legs. With the parts dangling in a vice or a pipe, center punch three or four places between the two parts threads. This "peening" of the thread locks the parts together. Spray paint the bottom shell half before inserting the legs in it. The locking washers go between the shell and outside nuts, which are now run up the thread. Lock them down tightly. Remember that you won't have any access to retighten them later if they should loosen up. Screw the remaining nuts 1-inch up the allthread. Run the coupling nuts gently up against them. The lower nuts are used as locking devices for the coupling nuts. Level the furnace base, and lock the nuts. Later, the additional lengths of allthread are used as extensions to raise the height of the furnace for large melts. The rest of the time, a lower center of gravity is better, even though the outward angle of the legs automatically increases the base size along with the added height. Still, it is best to keep the distance that liquid metal falls to a minimum. But, the furnace must sit high enough in the sand filled bucket to

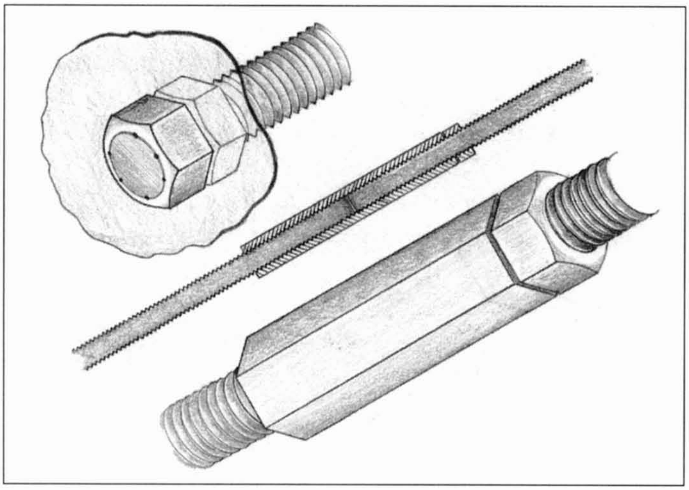


Fig. 9-4 The allthread is shown screwed into both ends of the coupling nut; the additional nut serves to lock one side of the joint to the allthread, while the other side is left free to be adjusted for height. In the middle is a cutaway view of the same joint. On the right is a see through illustration showing the peened end nut along with a section of furnace shell with the allthread leg and its locking nut on the bottom side.

accommodate all the spilled metal from a shattered crucible. So, leg additions for the occasional large melt are prudent.

8. Mounting the handle and attaching the lid

The handle is a "U" shaped 1/4 x 1/2-inch flat bar, part # 24. Bend the bar up 90° at 6-inches from one end. Make another 90° bend 6-inches further along to form a "U" shape. Even up the two ends. Place the handle against the lid's front side and weld it on permanently.

The furnace lid hinge assemblies are made from 1/4 x 1 1/2-inch flat bar. Three of them are cut 2 3/4-inches long, part # 25. One of them is cut 7-inches long. Lay out the four pieces for 3/8-inch holes, which are centered and 2-inches from one end. Cut a 1/4 x 3/4-inch setback on the end furthest from the holes. Three of the parts have the other end ground into a matching radius around the outside end of the holes. The fourth part is only ground around one corner of the end. The other corner is left. A hole is drilled for one of the "S" hooks near the corner. This part becomes the top member of one of the two pairs of parts. It and the other top part are placed on the hinge assembly's outer sides when mounted.

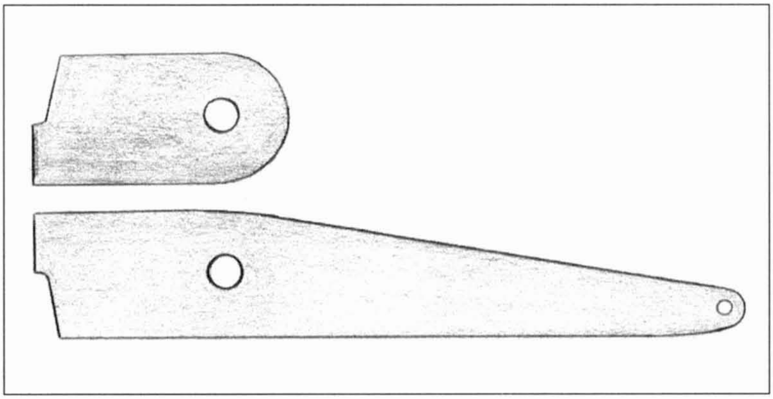


Fig. 9-5 One of the three standard hinge tabs and the long tab. Note the exaggerated cutbacks on the ends away from the holes. This is done to facilitate welding. The long tab allows the locking pin to hang away from much of the furnace heat. It is not safe to use this extended hinge tab for a handle.

Screw the coupling nut onto the 3/8 x 4-inch length of allthread, and center these two parts. Place the two pairs of flat bars on the two threaded ends, and screw on the nuts. Make sure their cutbacks are positioned over the furnace section to which they are not welded. It is best for the hinge assembly to be centered over the two legs on the burner port side of the furnace, so that you end up handling the crucible on the side away from the burner and its fuel hose. The fourth hinge part has been constructed to hold the linchpin away from the hot furnace wall when it isn't in use. The pin will still heat up, but not too much for gloved hands.

Check to make sure the furnace is sitting level. Align the lid with the furnace bottom, and place the hinge assembly in position over the burner port. Tack one of the bottom flat bars and then check that the assembly is sitting level. Tack the other bottom flat bar. Tack both top bars, and then gently raise and lower the lid to test the assembly's performance. Finish weld the tacks. Then, loosen the two nuts enough to let the lid move freely and cut off the excess allthread. Install the linchpin chain at your convenience.

When the lid is lifted up a linchpin, part #26, is inserted through a hole in the flat bars. Then the lid is allowed to close until the hinge closes against the pin, leaving the lid erect and leaning forward slightly over the exhaust. This position is a neutral balance point, so there is little tendency for it to overbalance the furnace. The lid is also being continually heated by the exhaust gases, thus increasing efficiency when doing multiple pours, while reducing stress from thermal shock. Yet, the lid sits clear of the crucible, so it creates no interference during removal and placement.

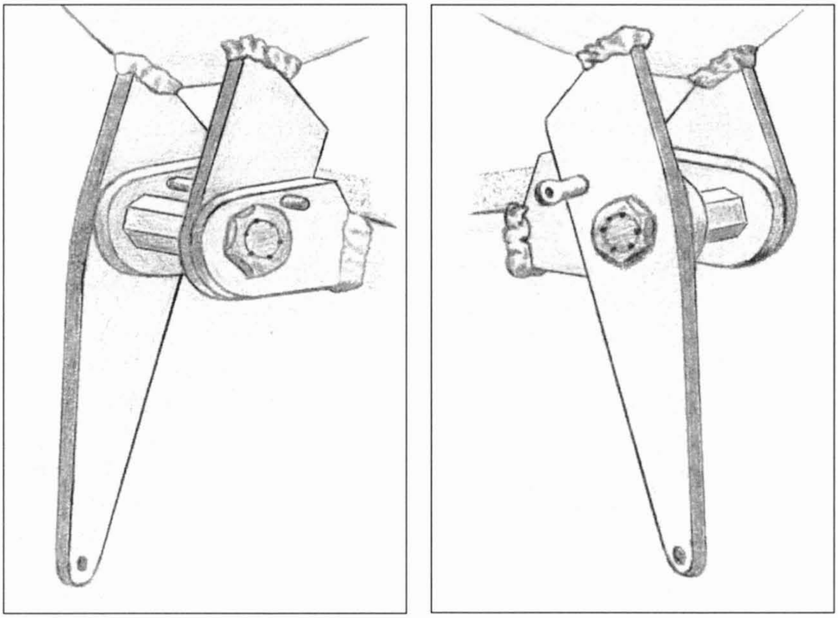


Fig. 9-6L and Fig. 9-6R Left and right views of the hinge assembly. Note the cut and peened allthread. Also note the flattened and drilled end of the linchpin.

Once the lid is mounted, open it and then let it close until the bottom of its forward edge is even with or just a little way beyond the inner edge of the furnace wall. Clamp the flat bars in position with locking pliers. Drill a 1/4–inch hole for the linchpin through all four bars. Use "S" hooks or open the chains end links to install it. Lift the lid and insert the bolt into the hole. Allow the lid to rest against the linchpin. When not in use the pin dangles on the chain, far enough from the furnace body not to overheat. It will rest out of the way, and be ready for use when needed (a fastener assembled version is given further on).

9. Installing the self drilling screws

Even if you weld the rest of the furnace parts, it is best to use threaded screws instead of welded stubs to retain the refractory. The screws are capable of some movement, which will ease the stress caused by their different coefficient of expansion. Since they aren't airtight, they provide escape holes for live steam during the curing process. Place screws at least 1 1/2-inch away from the edge and every four to six inches all the way around the circumference of the lid. Run the screws into the shell until they are snug. There isn't any need to risk over tightening because the refractory will finish securing them, just as they secure it. Use screws in the same pattern on the bottom shell.

10. Building a plinth

Refractory mixes come in two types. There are rammables, which are meant to be treated similar to clay. There are also castables, which are meant to be poured, but not like a liquid. They are more the consistency of brick mortar, and are treated much like it. Once a particular kind is chosen, you must follow the manufacturer's recommendations. Do not change the water content in order to treat a castable as a rammable or vice versa. Keep the bags dry and stir the premix with the complete contents of the bag before using part of it. Don't make up more than you can use within twenty minutes.

If you have never used castable refractory before, then a practice run is wise. Eventually, you will desire one or more plinths for use as positioning aids with small crucibles. This disc or raised platform should be of small enough diameter to clear the flame path; its height depends on the crucible size. It should have runnels (recessed areas to channel spilled charge from a broken or tipped crucible) on its bottom side. Building one, somewhere between two to four inches high, can give you the opportunity to practice mixing and tamping techniques before committing to the furnace lining.

Choose any suitable outer container, such as a dog food bowl, that can release or be cut away afterwards. Employ a small clear glass bowl or water glass as a hollow inner form, through which to view the tamping process. Cut candles, to be wedged between the two forms in order to center them and leave runnels at the desired finish height.

Mix a small amount of refractory and pour it into the outer form up to the middle of the candles. Use the edge of the spoon to tamp the mix into the form's corner areas, and its flat to pat the finish until you observe a whetting action start in the mix as water is forced to the top. Wait until you can feel the mix start to firm up as it sets, then gently place your inner glass form on the surface; it will sink in a little. Center the inner form with the candle pieces. Spoon and tamp the rest of the mix into the space between the two forms, with the absolute minimum tamping needed to achieve a solid mass. Observing the process through the glass teaches how much tamping is needed. The inner form will have to be heated with the burner and chilled with water to be removed without ruining the plinth. Don't forget to use safety glasses! You might decide that using the glass form is so appealing that you employ it, setting on a short, wide candle base, as the form for the lowered lid furnace version. This method works well if you can find a suitable bowl size and shape, but make no attempt to save the glass form. You will only end up cracking the refractory layer.

Set and cure the plinth in accordance with the instructions given for the furnace lining further on. It is well to have another plinth ready to be poured before beginning the lining process, in case you mix up too much refractory.

11. Lining the furnace

Begin by separating the lid from the furnace bottom. The furnace lid and bottom are lined at the same time, but in different places. Prepare the bottom by carving a slight taper on one end of the candle, and then screwing it into the threaded hole in the furnace bottom.

A two-thirds refractory to one-third Perlite layer is mixed up and patted into place first. It should take up the outer half of the area to be filled. The outer layer insulates, but it is also much less prone to cracking around the retaining screws because the Perlite provides some cushion effect. Mix and pour the second layer of finish refractory into the bottom of the furnace until it is 1/2-inch below the bottom of the burner port (make sure the furnace is sitting level first).

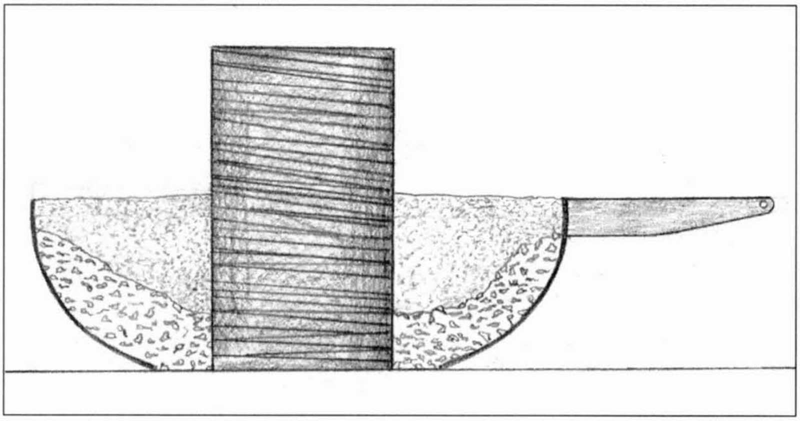


Fig. 9-7 The finished pour with both refractory layers. In the furnace lid's center sits the tape wrapped oatmeal box, which is trapped by the two layers.

Set the furnace lid, upside down, on an even surface. Use waxed paper between the support and the 5-inch shell opening (smear a little Vaseline on the paper). Peel the label off the 5-inch diameter sand filled oatmeal box. Wrap it in electrical tape (bottom and side), smear a light layer of the petroleum jelly on it, and place it in the center of the opening. Pour the refractory around it, gently tamping down as you go, and checking to see that the box remains centered (measure the distances to the shell edge). The second layer in the lid should reach the top of the curve. Allow the refrac-

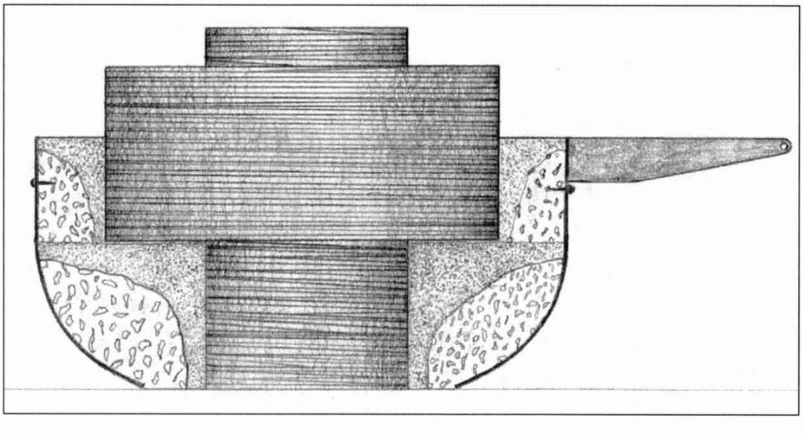


Fig. 9-8

tory to hard set before pouring the furnace walls. Use a spoon in placing the refractory and in tamping it down to collapse unseen voids.

Start the furnace wall with a small amount of pure refractory tucked in and around the bottom tube which the burner sits in. It is best to place the refractory, one spoonful at a time against the Vaseline coating and lightly tamp toward the forms. You do not want petroleum jelly migrating into the refractory's interior. Then use a Perlite mix in the outer layer, and keep it about 1/2–inch away from finish edges. Be careful to tamp down the inner refractory layer to eliminate air pockets. When you reach the top of the lid, use a straight edge (piece of wood, flat bar, etc.) to pat down the finish into a flat plane. It is desirable to let the refractory build up just a little higher than the edge of the lid. Later, it can be sanded flat with a #24 grit flap-disk. Let the refractory cure for several days, with wet towels draped over the parts. Once the refractory is completely hard set, melt out the candle from the inside of the hole. Use a coffee can or other metal container to catch the melting wax. If it catches on fire place a metal lid or piece of sheet metal over the pan to smother the flames. The point is to keep the wax from spreading all over the floor, and then bursting into flame. Open the lid on the box of salt, pour out its contents, and gently remove the empty box (you can slit its side with a knife to promote removal). Note that the exhaust opening in the refractory is about 1/2-inch away from the metal shell, all the way around its circumference. This keeps the shell from being eaten away by the hot exhaust gasses.

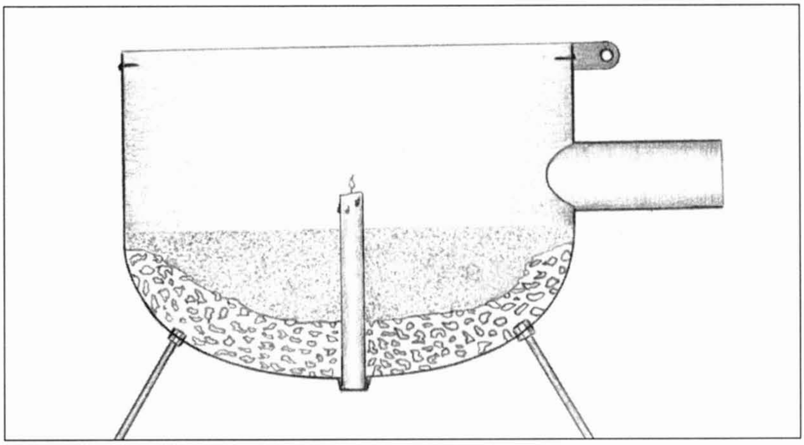


Fig. 9-9 The first section of pour (both layers), which end bellow the burner collar. This prevents molten metal from reaching the burner before it can exit down the drain hole. Note how the excess pipe is ground flush with the inside of the shell.

If you are making the lowered joint height version of the furnace, than the lid is constructed the same way as the furnace bottom. You will need to make a second inside form similar to the one given for the furnace base. Then, make a second pour in order to create a wall in the lid section as well as the base section. This form has two cardboard spacers instead of just one because the oatmeal box is more substantial than the candle.

Start the curing process by covering the two parts with damp cloths to insure that they dry slowly over several days (minimum of 24 hours). Taking several days to get a hard set is the first line of defense against serious cracking. Lower temperatures will lengthen the setup time. But, the refractory must be kept from freezing during the air set to avoid damage from ice crystals forming in its water content.

After the second day of curing, an 8-inch diameter piece of Sonotube (a heavy walled concrete form available at hardware stores) or a cardboard roll from a carpet store is placed in the middle of the furnace base. First, lay the tube over a piece of cardboard and mark the ID of the tube on the cardboard. Cut out the cardboard and push it into the bottom opening of the tube. Tape the cardboard to the tube, creating a solid face of tape. Cut a hole through this faceplate and push the whole form over the candle, which will help to keep it centered.

If you can't find either of the cardboard forms, use an empty 3-# coffee can. Cut a hole in the center of its plastic lid (match its size to the candle). Place the lid on the can, and tape over any indentations in the can (pull it tight so that it remains rigid).

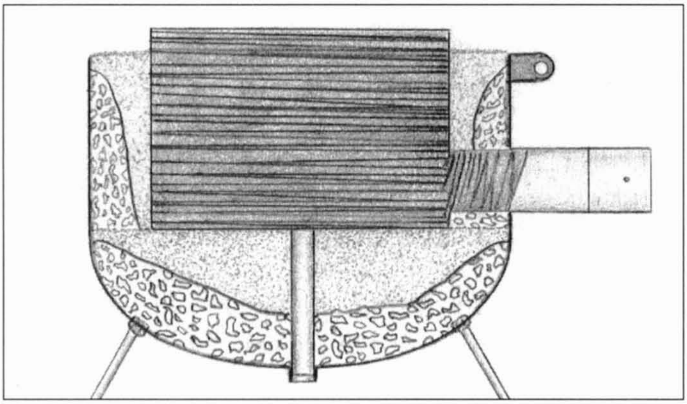


Fig. 9-10 This cutaway view exposes a tape wrapped cardboard form over the candle. A partially taped horizontal tube forms a tunnel from the burner collar to the vertical form.

Wrap the can in cardboard until its outer diameter is 8-inches, and then encase it in electrical tape. Smear the outside wall lightly with petroleum jelly, and place the form over the candle. Use a weight to keep the can from 'floating" in the refractory

The second pour in the furnace bottom and the second pour for the lid with the lowered joint height are nearly identical. Fig. 9-9 shows a second form over the first. If you mentally substitute a candle for the wider oatmeal box, this would be a drawing of the furnace base pour. Its inner refractory layer is tamped down around the vertical cardboard tube. Both the inner and outer layers are tamped down around the horizontal cardboard tube

Cut a hole in the bottom of the cardboard roll, or in the thick cardboard layer surrounding the coffee can, just a little larger than the diameter of a cardboard cylinder from a toilet roll. Remove the four thumbscrews nearest to the furnace body, and run the outer four thumbscrews together to form a cross. Wrap tape several times around one half of the roll, and push the other half into the inside of the burner port, place the Sonotube or coffee can on the furnace bottom and push its hole over the cardboard cylinder. You may need to cut the cylinder's end at an angle. It may also be necessary to slit the half of the cylinder that is pushed into the burner collar. Tightly pack the cardboard cylinder with waded-up paper until it crowds up against the thumbscrew barrier and protrudes into the Sonotube. Place tape over the protrusion in order to help maintain pressure. Tape the tube to the bottom of the furnace, and then pour the tube full of dirt. Smear a light coating of jelly on the horizontal form.

Mix about a quart of refractory at a time, and place it around the form in layers. Begin by cautiously placing the refractory around and over the little cardboard tunnel. Gently tamp each layer down to get rid of air pockets. Especially with the first few layers, check to make sure the form remains centered. Work your way up to the top of the furnace shell. As with the lid, try to allow the refractory to end up just a little above the shell's edge.

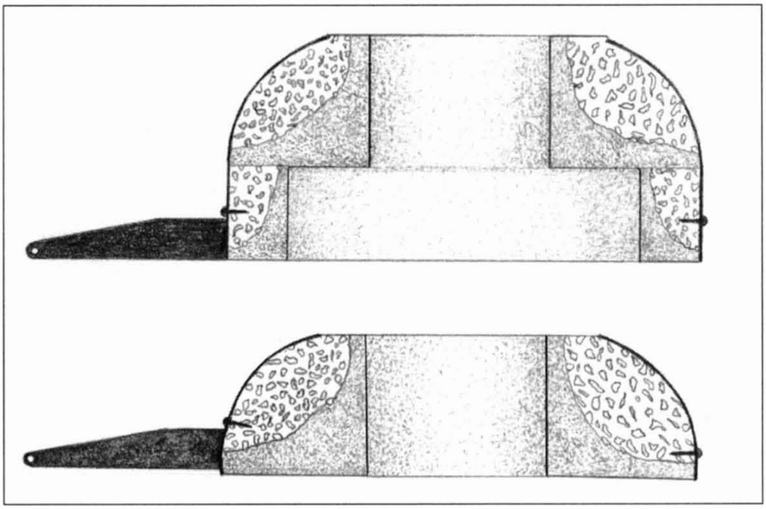


Fig. 9-11 A sectional view of the two different furnace lids. The refractory has hard set and the temporary forms have been removed, exposing the exhaust exit.

Check every few hours while the refractory is hard setting. Once it is firm, but before it fully hardens, scrape off most of the excess. Later, you can level it completely with a 24-grit sanding disc. Only after you're certain that the refractory is thoroughly set, pour out the dirt, and peel away the forms. Let the refractory completely hard set before removing the forms or its surface is likely to be damaged. Patience is the most important tool you can use in the furnace's construction.

12. Heat curing

Once the refractory has hard set, actively drive off the water by heating. If, at any time, you hear a pinging noise, back off of the heating until it stops. The noise is caused by the refractory cracking. First, raise the temperature to around 140° F. You do this by passing the burner around the heated parts (outside and in) from about an18-inch distance. Each time you pause to let the heat sink in to the refractory, check with a quick touch; 140° F is just beyond uncomfortable. A little patience will allow you to take both parts to this heat and keep them there until no more water vapor escapes, work back and forth between the parts to lesson waiting times. Or, you can assemble the furnace, and prop an old hair dryer at, but not in the burner opening or the exhaust for six hours. Prop the lid open a fraction of an inch to allow water vapor to escape from the faces of the upper and lower linings. At this point you can bring the heat up past 250°F by placing the burner in the collar, running it on low, and turning it on and off. Check the heat by putting a drop of water on the furnace lid now and then (it should boil off, but not bounce). Do this for two hours. Then, turn the burner up until you begin to see a little color in the refractory, then back down for ten minutes. Repeat this cycle for two hours. Let the two parts cool down enough to assemble the furnace. Turn the burner up until the inside of the furnace is red hot, then turn it down until color is gone. Repeat this cycle for two hours. Run the furnace up to orange heat for an hour. Run the furnace up to yellow for an hour. Run the furnace up to yellow/white for half an hour and you're finished.

What just happened was water removal at 140°F to 250°F. Forced removal of interior moisture happened at 425°F to 500°F. Cycling at color heats drove out the last of the chemically bonded water between 500°F and 900°F. Finally, the higher heating cycles, after all water was removed, vitrified the refractory mix into waterproof ceramic above 1800°F. Note that if the higher heat is not reached, you will not attain vitrification, which means that you will not have water proofed the refractory. Even with vitrification, its unsealed surface can collect moisture. It is always wise to store the furnace in a dry place.

With a hand burner, you are at risk from hot shrapnel, should you overheat the refractory enough to provoke a steam explosion. Proper clothing and a welding helmet (see Chapter 1) is a good idea for torch drying. You can order temperature sticks from a welding supply store to more exactly gauge heating temperatures. Ninety-nine times out of a hundred, nothing will go wrong. Still, it is best to be prepared for a case of rotten luck.

13. Finishing the shape of the exhaust port

In order to promote good venting and reduce noise, a concave relief is ground into the inside bottom face of the exhaust port. It should be between than 1 1/2-inch and 2-inch deep and wide. Use a #24 grit flap disk, and don't forget your respirator. After the main shape is ground in, switch to a sixty-grit disk and smooth the surfaces. Use sandpaper to radius the finish edges.

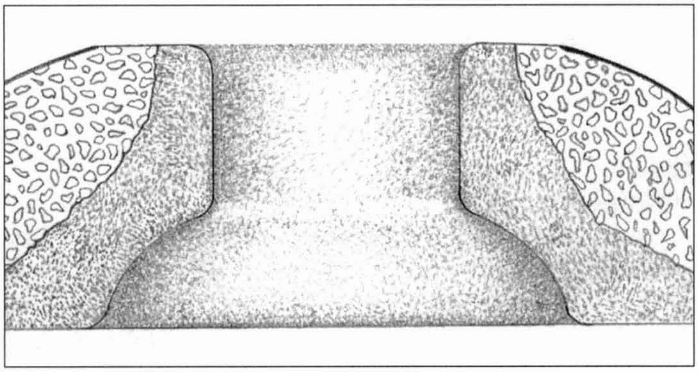


Fig. 9-12 A radius on the top and bottom edges generates less noise than sharp corners would. The concave curve in the lower half of the exit hole tends to further reduce the noise level, while encouraging a better draw for the spent gasses.

14. Applying finishes coatings

ITC-100 is applied only after the refractory is fully heat cured. This coating is used to seal the surface as well as reflect infrared energy, and can promote steam explosions if all water has not been driven out of the refractory before it is used. Brush any debris from the lining's surface and then paint on the coating following the directions on the bottle (or look them up in Chapter 5). Coat only the inside surfaces bottom, top, and vertical wall. Do not coat the top face of the vertical wall or the area of the lid, which rests upon it. The coating does not air cure. You must bring the furnace to red heat to finish the application process.

When you scrape the excess refractory from the top edge of the furnace wall and the face of the lid, the process will leave them rough. This will happen when the pieces of filler material (grog) pop out of the binder, leaving voids in the refractory surface. The surfaces can be improved with a finish layer (or several finish layers) of bonding mortar. Even with mortar such as Sairset which air cures, you should place a metal spacer between the two faces to hold them apart and run the furnace up to nine-hundred degrees to make sure the faces can't glue together. This should be done only after completing the air cure on every layer. Although some flame escaping around the lid's face shouldn't cause problems, mortar can be used to achieve a perfect seal if needed. This becomes especially desirable with the optional lowered lid configuration.

Fastener Assembled Version

If you don't want to weld or braze parts to the furnace shell, than you can use this plan to bolt and screw all your parts to it. Lengthen part #2 ,1 1/2-inch ID pipe, from 4 3/8-inches long to 5 1/8-inches long.

Constructing the burner collar

Begin by inserting the cardboard roll into the pipe and following the fitting procedure laid out in Step 6 for making the final adjustments to the shape of the hole in the furnace shell. This collar has the same thumbscrew pattern and is mounted in the same position as in Step 6. The pipe is longer because part of its forward area will be cut away to form tabs. They are then bent outward at 90° angles, drilled, and pinned to the inside of the furnace shell with screws. This plan is necessary because the angle at which the collar sits is too great to reach with a ground close nut.

Begin by rolling a piece of paper, 4 1/2-inch wide, around the pipe. Mark the place where it overlaps, and cut off the excess. Then, make a mark 1 1/2-inch down from the top at both edges of the paper. Fold the paper in half with the 1 3/8-inch marks together. Cut the end off the paper diagonally from the marks to the corner of the fold.

Spread the paper out flat, and draw a line down the fold. Draw lines midway between the fold and each of the edges. This will give you three lines and two edges at the top end of your layout template. When the template is placed back around the pipe its two edges become a fourth line, giving four places to take the layout for the anchoring tabs. On the bottom of the paper draw lines (with different colored ink or pencil) two inches on either side of the fold. The layout lines for three rows of thumbscrew holes are marked by the lines only; the paper edges are not part of the layout on this end. Place the paper back around the pipe with the paper's bottom

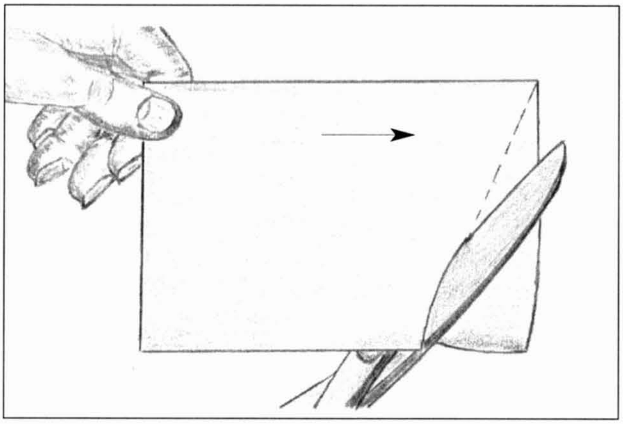


Fig. 9-13 Starting 1 1/2-inch down from the top edge, a diagonal line is cut back to the corner of the center fold. This template is made 3/4-inch shorter than the pipe to leave material for the short tab.

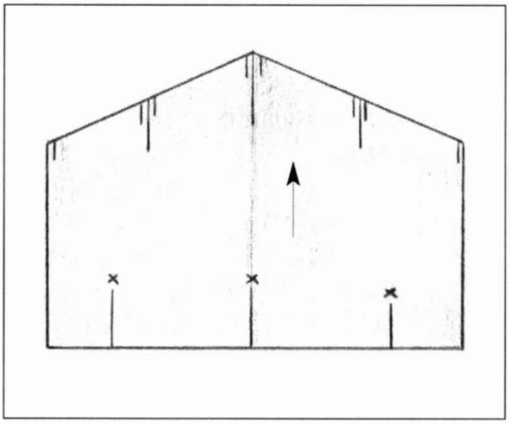


Fig. 9-14 Short lines show the tab edges at the top end of the template, outlining the positions of four tabs when it is wrapped around the pipe. The three bottom lines and "X"s denote the hole spacing, but not distance from the edge.

even with a pipe end. Tape it tightly in place. Use the 1/2 x 1/2-inch angle to transfer all four lines to the that end of the pipe. Ink mark the ends of the three lines on the pipes edge.

Push the pipe and paper template 3/4-inch through the burner hole in the furnace shell with the diagonal edge lined up as nearly as possible, and the point at the horizontal. Redraw the line on the pipe using the shell to give the correct curve and the paper edge to maintain the correct entry angle. Withdraw the pipe and permanently ink mark the line that you traced off the shell to the pipe. Use a scribe to mark the positions of the three bottom lines on the edge of the pipe, then use the angle to make lines about 2 1/2-inches long (keep them away from the four lines at the pipe's other end. Follow the instructions given in Step 6 for installing the thumbscrews.

Afterward, scribe parallel lines 1/4-inch on each side of the four longitudinal lines for the tabs. Drill 1/8-inch holes at each corner where the scribed lines meet the diagonal curved lines traced from the shell. Use the angle grinder with a cutting blade

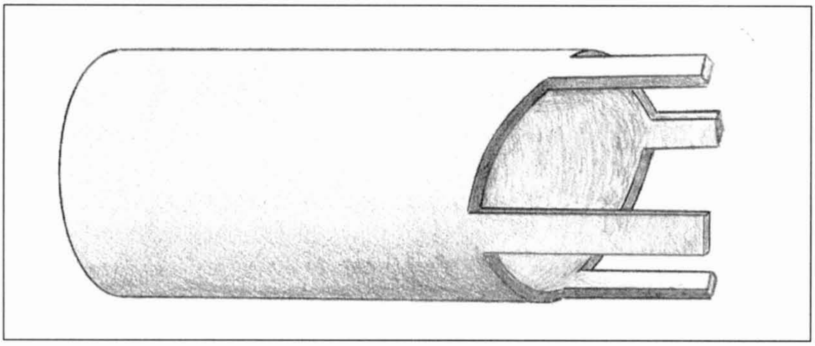


Fig. 9-15 The collar's tabs will be bent outward so that the pipe end sits flat as possible on its edge, then they are bent to match the shell and drilled.

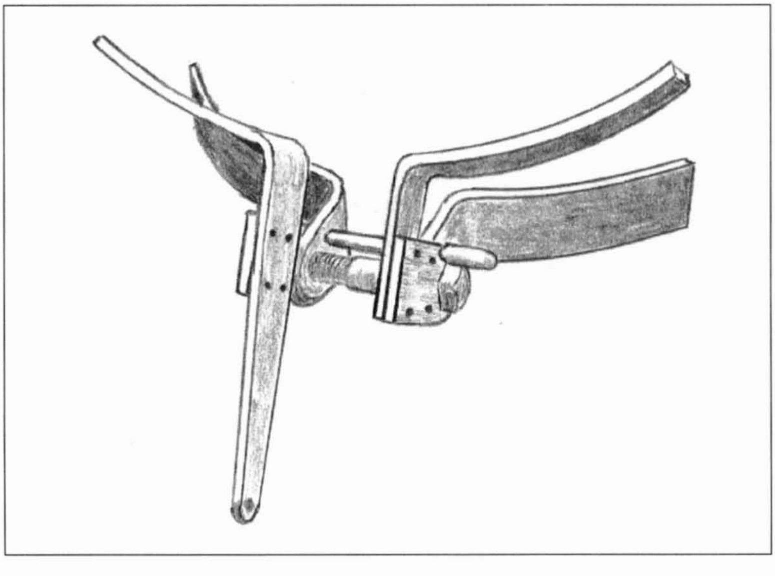
to saw down the scribed lines from the pipe end to the holes. Then cut the diagonal lines by laying the saw on the pipe and letting the blade sink into it until you are close to the holes. Do not attempt to match the line's curve (that is unimportant). Bend the material back and forth with the locking pliers until it snaps off. Grind or file the corner sections even with the rest of the cut line. Bend all four tabs outward at right angles to the pipe. Drill 1/8-inch holes centered and 1/4-inch from each of the tab ends. File away all burrs and flat spots inside the pipe.

Place the pipe inside the furnace and shove it through the burner hole. Line the tabs up properly and use the drill to mark the shell where the shortest tab lines up. Remove the pipe and drill the hole. Enlarge it to 1/4-inch. Then drill the tab hole out with a #21 bit and thread it with a #10-32 tap. Reassemble the pipe and shell, and then fasten them together with a screw. Move to the opposite hole and repeat the process, then do the other two holes. Any necessary adjustments can be made with washers between the tabs and the inside of the shell so as to achieve a perfect aim (see instructions in Step 6 for aiming the burner).

Mounting the handle and attaching the lid

The handle is a "U" shaped 1/4 x 1/2-inch flat bar, part # 2. Drill three 3/16-inch holes at 1/4-inch, 3/4-inch, and 1 1/4-inch from each end. Next, make a mark at 2-inch from each end and bend them up at right angles. Then, find the bar's center and make a mark 3-inches on either side of it. Bend the bar down at right angles in both places. You should now have a "U" shape with drilled tabs on both ends. Place the handle against the lid's side. You will notice that the tabs need to be hammered down so that they match the shape of the 12-inch cylinder (which your lid was cut from). Clamp them, heat them to red with the burner, and hammer them over in a curve (hit the end to promote curving). It is easier to over bend them, and afterward flatten them out to reduce the curve. Once you have a good match to the lid, drill

Fig. 9-16 Perspective view of hinge assembly. The curved legs are about 6-inches long, relieving the need for an exact fit and increasing the distance between screws. This lighter flatbar is recommended for easier bending. The lowered lid version should be used here. It creates less stress on the hinge because the weight is better balanced.



through the outermost holes with the 3/16-inch bit, and fasten the handle with #10 -32 screws and nuts. Then, repeat the procedure with the rest of the holes.

The furnace lid hinges are made from 1/8 x 1-inch flat bar (part # 25), bent into brackets and pinned. Begin by drilling three 3/16-inch holes at 1/4-inch, 3/4-inch, and 1 1/4-inch from each end of the 2-foot bar. Next, scribe a mark at 6-inches from each end. Curve the 6-inch areas to match the 12-inch radius, and then bend them up at right angles. Make a mark 7-inches from the bend and cut off the one bracket. Make a mark 2-inches from the bend for the other three brackets

With the curved leg facing up, center punch the long bracket's straight leg at 1 1/2-inch from the bent. Clamp a second bracket to it with their curved sections evenly matched against the furnace's curve. Drill a pilot hole and then the 3/8-inch hole through both of them at the same time. The shorter of the two parts has the end corners ground into a matching radius around the outside of the 3/8-inch hole. The long part is only ground around the upper corner of its end. The lower corner is left square. A hole is drilled near the corner. These two parts become the bottom set of the two pairs of parts.

Next, drill 3/8-inch holes at 1/2-inch from both ends of the remaining flat bar, and grind their outside corners into matching radiuses Then cut off the two drilled ends at 2 1/4-inches. Clamp one piece to the end of one of the second pair of brackets, so that it is facing down with the curved leg facing out. Place it on the opposite side of the bracket from the curved leg. Check the fit by placing one of the first sets of brackets next to it and placing a bolt through the two 3/8-inch holes. If the leg lengths don't match, adjust the clamped joint until they do. Then check the assembly for it on the furnace. Drill and thread the joint for a #10-32 screw near any available corner of the two pieces. Run a screw in tight from the curved leg's side of the joint, and then repeat the process in the other three corners. Grind away any excess thread. Make up the other bracket the same way.

Screw the coupling nut onto the 3/8 x 4-inch length of allthread, and center the two parts. Place the upper and lower brackets on the two ends, and screw on the nuts. The first pair of brackets is the lower ones. The second pair of brackets are the upper ones. Make final adjustments to the fit and fasten the hinge using the same methods as you did for the handle. Any further fitting problems can be eased by the use of washers as spacers. It is best for the hinge to be centered over the two legs on the burner port side of the furnace, so that you end up handling the crucible on the side away from the burner and its fuel hose. The linchpin is installed according to the instructions given in Step 8.

If you haven't built a forge, you can assemble four firebricks on a nonflammable surface into a "heat tunnel in order to conserve the burner's energy. Place the flat bars through one end, and run the burner at the other end. Turn the burner off each time you withdraw a flat bar for hammering.

WARNING!

Any material added to the hot crucible must be preheated to insure that all moisture has been forced out of it. Even when metal looks completely dry, it can have water residing in its outer crystalline layers. Forgetting this safety rule has caused numerous steam explosions. Steam explosions turn furnaces into molten metal cannons. Always preheat the material to be melted.

So, how much? A drop of water will bounce off the material at 400° F, and you can be sure you're safe. Hold the material to be added with tongs and preheat it in the furnace exhaust gasses before placing—not dropping it into the crucible.

Running the furnace

(1) The crucible is loosely loaded and set in the furnace, centered over the drain hole. You must remember to provide room for the charge to expand before it melts. This is important even with a steel crucible. Do not overfill the crucible.

(2) The burner is started at minimum pressure, with the furnace lid pinned in the open position. Slide the flat washer back away from the portal's entrance. Slide the burner's choke forward until the space beyond the accelerator tip is exposed. Use a flame held below it as you gently open the gas valve. Slowly open the valve further until the flame is blown down the mixer tube and onto the burner nozzle. If there is moisture collected on the furnace walls, the burner may blow out several times before the steam is cooked out and no longer causing interference.

(3) After a few minutes warming the furnace lid is lowered into place, and the washer is slid closed against the portal. A few more minutes are given to bring the entire interior to an even heat and then gas pressure is slowly raised to the desired level. Observation and loading is done through the exhaust hole. Be careful to look into it from an angle using eye protection. Once the interior becomes incandescent use UV/IR filtered glasses to defend against flash burn.

(4) To remove the crucible, first turn down the gas pressure to an idle, then lift and pin the lid in the open position. While wearing proper safety clothing, lift the crucible out of the furnace with properly matched tongs. After use, replace the crucible whether you plan to do another pour or not. The furnace is the safest place to store a hot crucible, and this will save unnecessary thermal shock with ceramic models.

(5) Allow the furnace to cool down slowly, while the burner is still left idling if you are using a ceramic crucible. The kinder you are to the crucible, the longer it will last. When the furnace has cooled as much as it can with the burner running shut the burner down. If you are using a ceramic crucible, close the burner choke to help slow cooling. Follow the safety procedures given in Chapters 1 and 5 for shutting off the gas and handling the fuel cylinder.

10

Farrier's Forge

Clamshell forges are an optimum shape for heating horseshoes. This enables the traveling farrier's forge to be made compact and powerful. It also permits the use of smaller burners. Clamshell shapes can be made from a small sheet metal barbecue or five-gallon propane tank. This model will employ the cut down tank; using methods already discussed at length in other chapters and referring to those passages along with their drawings. See the Clamshell Forge section in Chapter 6.

A large quantity of Rigidizer is employed in its construction in order to turn the refractory blanket into a completely rigid and tougher form. It is less insulating, and is a trade off of some efficiency for a studier construction. This forge will still easily reach welding heat, but will be no match for the tube forge on straight parts. Because the flame's trajectory passes through the center of a round shape, then strikes the heat shield and is bent back around the work's periphery before exiting, it is capable of rapidly heating circular shapes, such as horseshoes and scrolls.

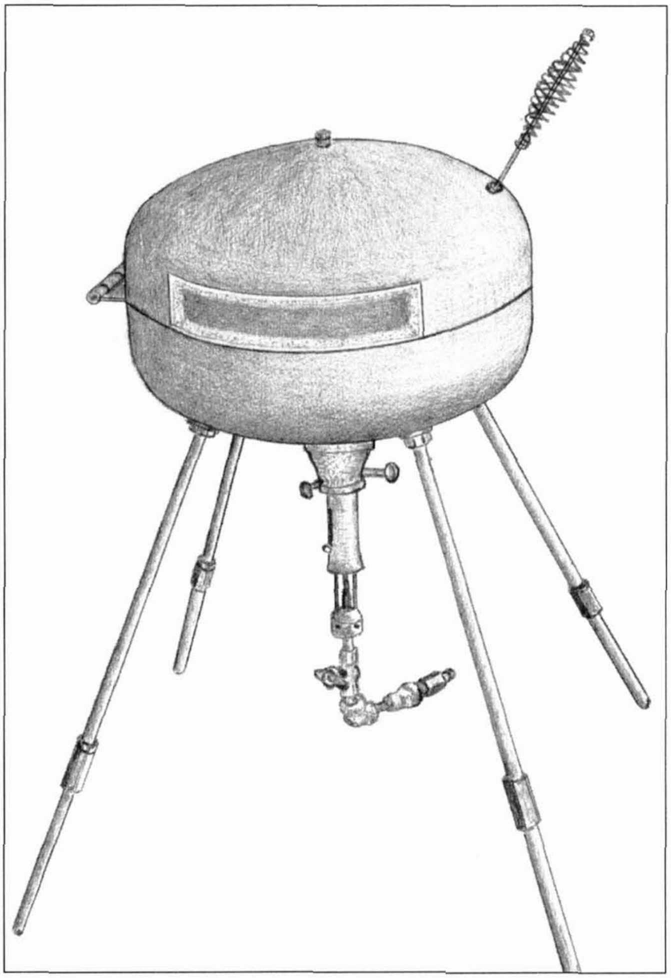


Fig. 10-1 Extendable legs and a quick coupling are featured in this design for fast setups. Note how the insulation is substantially narrower than the shell opening to keep hot exhaust gasses from overheating the metal.

Materials list:

(1) Five gallon propane cylinder (unused recommended)
(2) Can of barbecue spray paint
(3) Eight feet of 1/2-inch allthread (threaded rod)
(4) Twelve 1/2-13 nuts with four lock washers
(5) Four 1/2-inch coupling nuts
(6) 3 linear feet of 2-inch thick #8 ceramic fiber blanket, 2 feet wide
(7) One gallon of Rigidizer
(8) One pint ITC #100
(9) One 1/2 x 10-inch round kiln shelf and one 1/2 x 6-inch round kiln shelf
(10) One standard door hinge
(11) Four 10-32 x 1 1/4-inch SS machine screws and nuts
(12) Four 10-32 x 3/4-inch SS machine screws and nuts
(13) 1 1/2 x 3/4 NPT bell reducer
(14) 1 1/2 NPT short nipple, 3/4 NPT short nipple
(15) Three 1/4-20 x 1 1/2inch thumbscrews
(16) 1/2-inch jet ejector style propane burner, hose, regulator
(17) Two 1/4 x 4-inch SS carriage bolts with four SS nuts and two washers
(18) Possibly silver braze, flux, sandpaper

Tool list:

Same as Chapter 9 plus:
(19) 3/16 & 5/16 inch drill bits, 5/16-inch masonry bit, 2-inch carbide holesaw [1]
(20) Wood rasp or a coarse file

1. Making the forge shell

Prepare the tank by following the instructions in Chapter 5, Step 1. Next, set the tank with its foot-ring sitting upon a flat surface, and mark a line all the way around the tank's periphery about 2-inch up from its bottom curve. Use a block of wood to support the ink marker at the right height, and revolve the tank against its tip. Mark a second line about 1 1/2-inch down from its upper curve.

Now, follow the instructions in Chapter 5, Steps 2 through 4, to lay out a 9-inch circle. Then use the dividers to find and scribe four equidistant places on the circle and punch mark them for drilling. Next, Use the dividers to lay out a 2-inch center circle. Then, fill the tank with water up to the beginning of the top curved end and cut out the 2-inch center hole. Drill the four equidistant holes out to 3/8-inch and then enlarge them to 1/2-inch with a countersink or sheet metal step drill.

Lower the water level to an inch or two below the upper peripheral line and cut the top of the tank off with a cutoff wheel on an angle grinder; this will become the bottom of the forge. Lower the water level to an inch below the lower line and cut the middle section out of the tank. Use the sanding disk to clean the edge of the tank bottom before pouring out the rest of the water, then sand the burrs off the top section of the tank.

Turn the bottom tank section over, remove the foot ring, and clean the weld scars.

If there is a tarry mess on the tank bottom, cook the tank as described in Chapter 5, Step 6, otherwise wipe out the inside with rags and continue. Mark a line 1-inch up from the edge. Next, mark two lines at right angles and 9-inches apart. Cut this section out and deburr it. Turn the top over and use the cut out section and your tape measure to find the exact opposite position on the lid's lip. Mark each end of your template, cut out the second piece and deburr; this becomes the forge lid. Use the flap disc to sand off all old paint, then spray paint the exterior of both parts.

2. Constructing the burner collar

Tightly screw the 1 1/2 and 3/4-inch short nipples (parts #14) into the 1 1/2 x 3/4 NPT bell reducer (part #13). Then cut the 3/4-inch nipple off even with the reducer's edge. Cut the 1 1/2-inch nipple off 1/2-inch beyond the reducer's other edge. Mark three equidistant places on the nipples edge and draw lines 1/8-inch on either side of them, marking out 1/4-inch wide bending tabs. cut down the lines and then even with the reducers edge between them. Do not cut all the way to the tabs, but break off the weakened sections and then file the cuts clean. Drill and thread three equidistant 1/4-20 holes in the curve just above the reducer's bottom lip, and deburr all internal surfaces. Next, screw in the three thumbscrews (part #15). Then, insert the assembly through the forge shell's bottom hole and bend the tabs down against the shell. Finally weld, braze, or fasten the tabs in place.

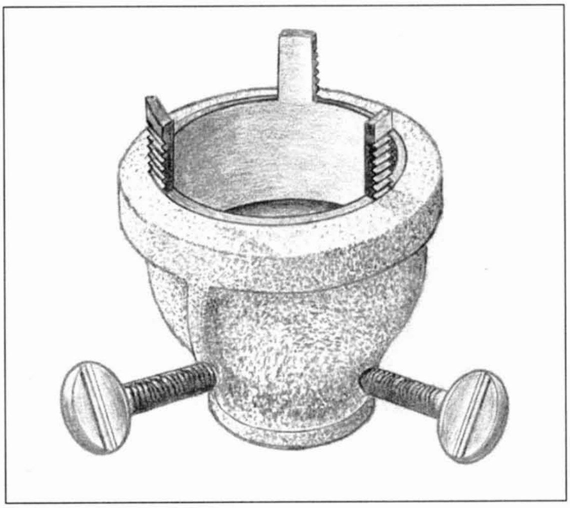


Fig. 10-2 The burner collar assembly is ready for installation. Note how the inner edge of the nipple is filed perfectly even with the reducer's lip for a tight fit against the shell once the tabs are bent down.

3. Mounting the legs

Cut the eight feet of 1/2-inch allthread up into eight legs; four of at 12-inch and four at 6-inch. Follow the directions in Chapter 9, Step 7, to mount the allthread legs. The short bottom sections can be removed, allowing the forge to sit in a box on the truck seat during transport. Despite the generous use of rigidizer, you should avoid physical abuse to keep maintenance work at a minimum.

4. Mounting the lid and installing a handle

A standard door hinge holds the upper and lower forge sections together. If you don't wish to weld or silver braze, then employ a bolted hinge assembly like the one featured on the fastener assembled furnace in Chapter 9. To use the door hinge, place one of the two cut out strips on one side of the hinge with about 3/4-inch as the distance of the two corners, formed by the curved line from the hinge. Ink mark a line and grind through it with a cutoff wheel, then use the cut section as a guide and continue grinding through the other face. Clean the burr and do the final shaping of both hinge faces as one. Place the lid on the furnace bottom with the openings centered over two of the legs. Make sure the edges are aligned and tape over the seam at the furnace front. Wedge the lid open about 3/4-inch on the backside. Center the hinge over two legs, and weld or braze it to the bottom shell. Place the other hinge face parallel with it, and fasten it to the top shell; this leaves a small gap between the two hinge parts, which is helpful in preventing accidentally welding the furnace closed.

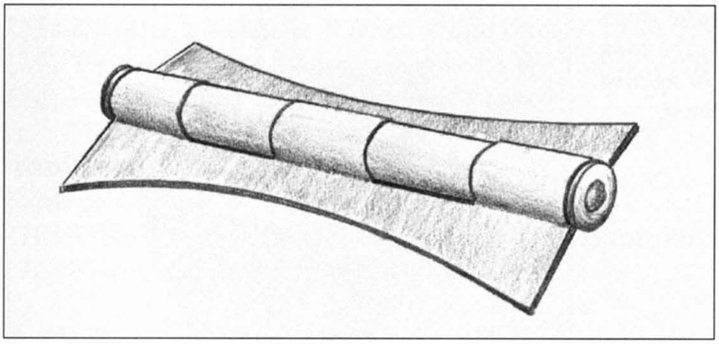


Fig. 10-3 The hinge's curved edge complicates leaving bent tabs for fastening; therefore, they are not recommended.

The handle can be anything that will serve. Flat or round bar, a screwdriver that has had the tip cut off and then threaded, or as in this example, a stove door handle spring on allthread. Place it on the forward side of the lid and pointing up at an angle. The two 3/4-inch SS screws in the materials list are for mounting a flat bar handle.

5. Installing the insulation and the bottom shelf

Use the carbide holesaw to drill a 2-inch hole in the middle of the ten-inch kiln shelf. Place the refractory fiber blanket over the bottom shell's edge and press down hard to make an impression in a corner of the blanket. Use a hacksaw blade or a serrated knife to cut along the impression. Place this piece in the bottom of the furnace, center the drilled kiln shelf on top of it and press down hard. Take the shelf back out and cut the concaved blanket into a flat plane. Replace the shelf, pierce a hole in the center of the blanket and press the material back to form a tunnel between the collar and the shelf. Remove the shelf again, and liberally soak the blanket with Rigidizer. Replace the shelf and push down hard, then place weights on the shelf to keep it depressed. Wait about 30 minutes while the Rigidizer helps the shelf to depress the blanket. Then, scribe a line parallel to the shelf, and at the same depth over one of the legs. Drill a 3/16 hole about 1/4-inch below the line, and push a 10-32 SS screw through the hole. Place a nut on the inside of the shell, and tighten the screw over the kiln shelf. Adjust your heights as needed to place four screws in contact over the shelf, to hold it down against the blanket's spring-back. Remove the weights, cut straight down the edge of the shelf all the way around and remove the excess blanket. Cut a 4-inch wide by 36-inch long strip of blanket, starting at its cut end. Then make a bevel cut along one of its edges. Liberally drip Rigidizer into the exposed blanket between the outside of the shelf and the shell. Soak the beveled edge of the strip with Rigidizer and press the strip into the gap all the way around the shelf. Make cuts where it straddles the screws, and push it down and then back against the shell. Make a preliminary trim down to 1/4-inch from the edge of the shell. Soak the rest of the of the strip including its top, letting some liquid run into the overlap between the strip and kiln shelf. Soak the tunnel section too. You should use about four-fifths of a quart for this soaking. Allow the Rigidizer to dry, and then heat it with the burner until its color turns white. Trim the top of the strip even with the furnace shell's edge by pulling a knife or saw blade through the blanket, toward the shell. Use about one-fifth of a quart to soak the cut edge again, and repeat the heating. Leave the refractory edge 1/8 to 1/4-inch above the shell at the exhaust openings, using the lid to designate these two areas.

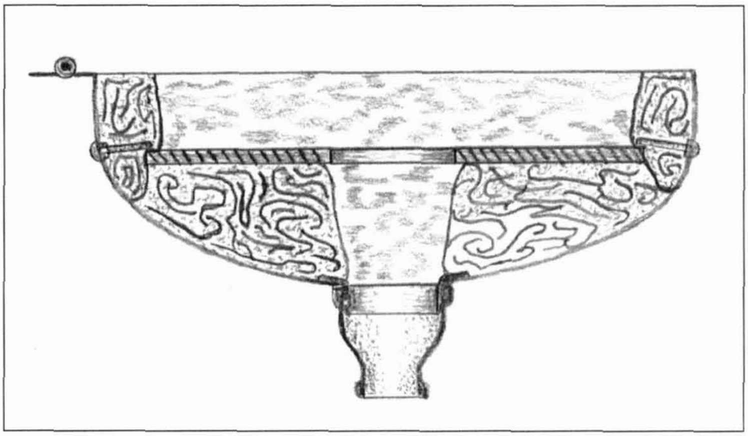
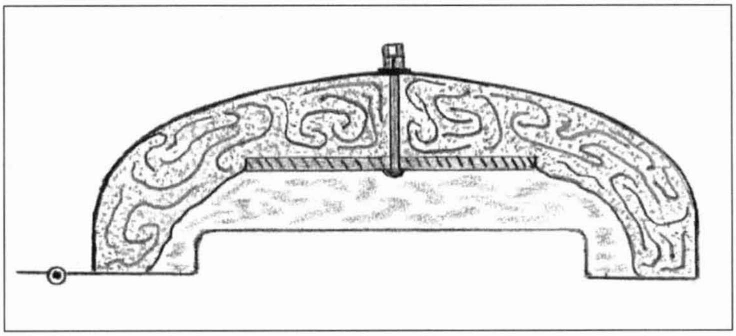


Fig. 10-4 Cutaway view of the forge bottom. Screws keep the shelf in place over the refractory bed. Note the bent over tabs, keeping the reducer trapped on the forge bottom.

6. Installing the insulation and heat shield in the forge lid

Leave the refractory edge 1/8 to 1/4-inch above the shell at the exhaust openings, using the lid to designate these two areas. Drill a center hole in the 6-inch kiln shelf with the masonry bit, and a center hole in the lid with the 5/16-inch bit. Cut a 24-inch square section of blanket, pierce a center hole, and then use the anchor assembly to hold the shelf in place, while pushing the blanket into the contour of the lid and pressing the shield down to increase the internal curve. Trim the corner pieces even with the rest of the excess material so that it becomes more flexible, and then push it further into place. After being rigidized, the convex shape contributes as much to holding the lid lining in position as does the heat shield. The rigidizing and final trim is done much the same as the bottom was except for the exhaust ports. When they are trimmed, leave about 1/8-inch excess; this keeps the exhaust gasses away from the sheet metal. Run the second nut against the first to lock it in position, and then cut away the excess thread.

Fig. 10-5



7. Curing and coating the forge

Close the lid most of the way, wedging something between the shell edges to hold the lining faces apart. Follow Chapter 5's recommendations for heat curing. After the forge has run at lemon yellow for half an hour, let it cool completely. Use the wood rasp, drawn back toward the shell to grind the edges of the rigidized linings until the shell edges touch. Soak and heat the edges a final time.

Paint all interior surfaces, including the exhaust openings with ITC #100. Do not coat the liner edges with it, except at the exhaust openings. Follow the directions in Chapter 5 for heat curing the ITC #100 coating.

Maintenance

Maintenance is the same as the forge in Chapter 5. Farriers might want to build a box for the main forge body so that it can travel on the truck seat, cushioning it against shock. Because the burner sits facing up, extra MIG tips and Teflon tape should be kept on hand in case of plugging. The left over fiber blanket can be chopped up and mixed with the left over rigidizer for repairs. There will be plenty of ITC #100 left over for the same purpose; remember to keep the spare Rigidizer and the reflector coating from freezing, which would ruin them. Shelter the forge as much as possible from drafts that drastically cut down on burner efficiency, forcing you to expend extra fuel. It is wise to keep an extra heat shield, anchor, and refractory repair kit on hand while traveling.

11

Multi-hole Glass Furnace

Darrin Strosnider, for whom it was developed, dubbed this configurable furnace the Multi-hole. It is a portable glory hole, vitrigraph kiln, and crucible furnace, capable of being fed from a five-gallon propane cylinder. The request came shortly after the jeweler's furnace finished trial runs, and it seemed to fit the bill. The furnace can also be used as a hanger bucket. It is the perfect size for a bead furnace when combined with a secondary insulation system.

It would be folly to recommend home-built burners on glass furnaces because no safety inspector is likely to approve them. However, it is only a question of time before someone manufactures these burners in response to the competition from hotter home built models. Meanwhile, a standard burner can be employed with this equipment by changing the burner collar into a portal that fits one.

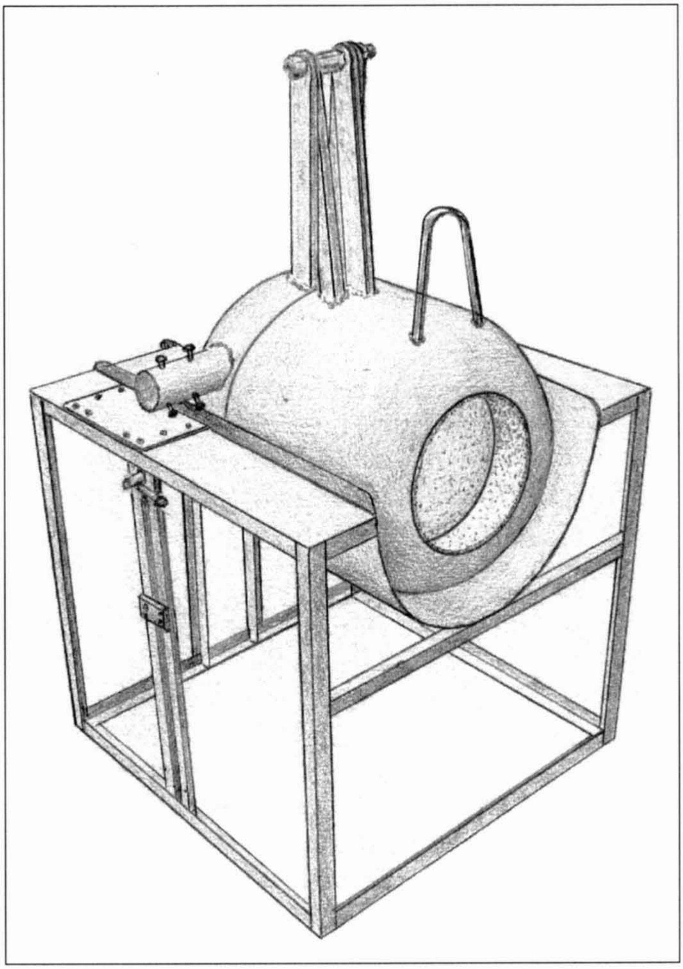


Fig. 11-1. The furnace is configured as a glory hole in this view. It is pinned at the top of the side slot and resting in the belly band. Only the top panels are installed at this point. The rest of the sheet metal covering is only desirable for those who want a bead furnace.

Materials list:

Use the Chapter 9 list with the following changes:
(2) Your burner choice; this one is sized for the 3/4-inch burner
(10) A Ransom gas burner, with flame guard system is recommended at this time.
(13) Change number of screws to a box if choosing mechanical assembly
(15) Change to 3/8 x 24-inch of allthread rod, three coupling nuts, twelve plain nuts
(16) Is changed to 30-feet of 1/8 x 3/4 x 3/4 steel angle
(17) 1/8-inch x 1/4-inch steel flat bar 1-foot long
(21) Becomes two approximately 2 3/4-inch diameter plastic pudding cups
(24) A 2-foot long piano hinge
(26) Becomes two 1/4-20 x 3-inch thumbscrews and nuts and five at 1-inch long.
Add a 4 x 8-foot piece of sheet metal (1/8 aluminum recommended) [1]
Eight 1/4-20 thumbscrews 3/4-inch long
1 1/2 x 1 1/2-inch angle (or larger) 1-foot long

Tool list:

The same as Chapter 9 plus a carpenter's square

Fabrication

This furnace is patterned on the one in Chapter 9 with some differences.
(1) A plug for its drain hole, which requires a larger hole diameter, 2 3/4-inch instead of the standard 1-inch.
(2) The furnace top is lowered extending below the tank's weld seam. Therefore, no retaining screws are needed to trap the furnace top refractory. The furnace top effectively traps the bottom refractory when the furnace is in the horizontal position, so no retaining screws are needed for it either. This is desirable because a single layer of pure refractory is recommended for this furnace.
(3) It has 10-inch long hinges, which give it a longer arc when opened and act as a handle for positioning.
(4) It has two front locks and axles instead of legs. These allow the furnace to tilt to a horizontal position and be used for a glory hole.
(5) The axles rest on removable pins at the top of slots so that the furnace can be lowered into its carriage, which can then be filled with perlite. With this secondary insulation, the equipment can become a bead furnace or hanger bucket. Otherwise, it is very similar to the lowered lid furnace version shown in Chapter 9. Therefore, drawings will be given with measurements, but the only building instructions will involve furnace differences and its carriage. Read Chapter 9 and refer to it for construction techniques. All metal work and painting should be completed before any refractory is poured. The burner collar is not installed until the furnace is positioned within the carriage because of the close tolerances involved. This model is designed to sit on the Chapter 6 cart, and therefore its carriage is a 19-inch cube without a bottom panel. A bolt-on lower cart can be added to make a stand-alone unit of it.

1. Making the furnace plug

Fill one of the plastic pudding cups with refractory, tamp it down, and then gently tap the cup on a flat surface until all the air bubbles are removed. Cap the cup to ensure a slow hard set and put it aside.

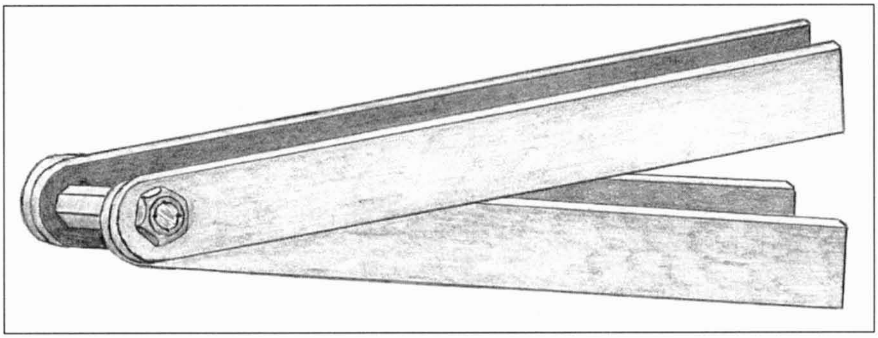
2. Laying out the tank

Cut the drain hole and exhaust opening. The drain hole is exactly matched to the plastic container size with a half round file. With the tank sitting on the exhaust opening, mark a line, 7 1/2-inch up, around the tank's periphery. This should be about 1/2-inch above the top edge of its weld seam's inside flap.

3. Making and attaching the two furnace sections

Begin by constructing the hinge assembly. It is made from 1/4 x 1 1/2-inch flat bar, pinned together with allthread. There is no extended tab for a chain handle as with Chapter 9s furnace because this version has a foundation in which to store its locking pin. Read the instructions in Chapter 9, section 8. If you are going to weld the hinges, change their cut dimensions from 2 3/4–inches long to 10-inches long and follow the rest of the Chapter 9 directions accept for the pin tab extension. For screw assembly, read the hinge section of the Fastener Assembled Version and lengthen the hinges to 10-inches, ignoring the extended pin chain tab.

Fig. 11-2 The four flat bars are trapped between a coupling nut and peened outside nuts. Angle irons can replace the top bars.



One of the differences between this equipment and the Jeweler's furnace is the position of the hinge assembly. The burner and its collar sit parallel to the furnace axis, so that they move very little as the furnace is configured; this is important with a flame-guard safety system. The hinge assembly is fastened at right angles to the axis so that the long hinges can be employed as a handle when rotating the furnace. They are pinned to the carriage when it is in either of the two vertical positions.

Make a 10-inch slit along the seam and attach the hinge assembly over this area before cutting out the rest of the opening. This helps minimize distortion and insures the best match up between the upper and lower furnace shells.

It is necessary to make a very careful layout and cut on the furnace seam in order to maintain a seal. Thus, preventing the hot gasses from entering the burner's air intakes.

4. Constructing the locks

Cut eight pieces of angle 3/4-inch long. Make a center mark on both of its flanges (see Angle in the Glossary for terms). On all of the pieces center punch and drill 1/8-inch pilot holes at 1/2-inch on the toes of both flanges. Enlarge the pilot holes to 3/16-inch on one flange of all eight pieces. Enlarge the remaining pilot holes to 5/16-inch on four of the pieces. Enlarge the remaining pilot holes to #7 and tap 1/4-20 thread into the other four pieces. A flat washer is used to mark a circular outline around the thumbscrew holes. Grind the excess material away.

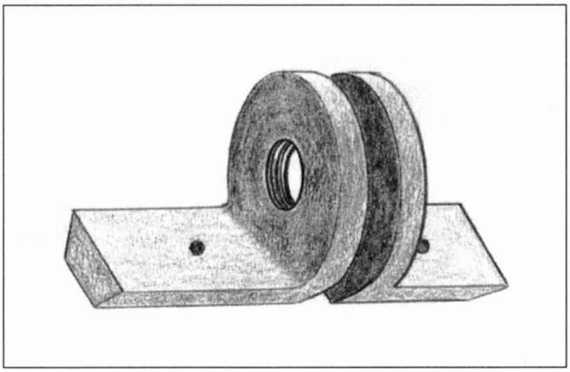


Fig. 11-3. The clips with 5/16-inch through holes are fastened at about 1/4-inch above the lip. They are spaced about 4-inches apart and opposite from the hinges. The two left over clip sets are used as axle pins on the side slots.

5. Attaching the axles

Establish two points at right angles from the hinge by measurement. Lay a straight edge across the shell face to double check for square and centering. Measure down from the edge to within two inches of the curved section's beginning and lock the square at this point. Use the end of the square to scribe crossing marks, and punch mark them and drill the first pilot, then 3/8-inch hole in both places. Keeping the axle as true as possible will be a help to you when the furnace mounts in its carriage. See Fig. 9-4 for similar construction. Center the allthread in the bottom section with a nut inside and coupling nut outside on the shell wall. Leave only 1/2-inch of protruding rod for the coupling nuts. Weld or use the burner to silver-braze the inside and outside nuts into permanent position. Cut away the allthread from the inside of the furnace shell using the grinder. The two coupling nuts left extending outward are now frozen in a straight line with one another, and will be used with short sections of allthread to form axles. This allows the furnace to rotate between horizontal and vertical positions. The extending allthread can be employed to mount spring counter balances later, if desired.

6. Building the carriage frame

The carriage starts as a cube, 19-inch on all sides. Its angle frame toes inward everywhere but the inside top angles (next to the furnace body). These angles are added later, so begin by constructing the simple cube. If you can't weld, these parts should be brazed together. However, you can use the sheet metal; cut into panels in order to screw everything together. The sheet metal goes on the outside. Either way, on the top and bottom faces use 45° gate cuts. All four vertical angles are square cut at 17 1/2-

inches long and placed between the top and bottom squares.

7. Installing the axle slots

Place the furnace in the cube with its axles protruding through the carriage sides, and its exhaust opening (glory hole) even with the carriage front. Make marks 1/16-inch on either side of the allthread and weld vertical angles toeing in and away from each other. Be careful to keep the slots thus formed parallel and in line with each other. Or, measure the distance from axles to the end of the furnace and mark it on the sheet metal sides. Scribe and cut out slots 1/8-inch wider than the axles and attach two vertical angles to the sheet metal with screws. They should still face inward. Weld or screw thumbscrew pins far enough below the top of the slots to give the axles 1/8-inch of vertical play. The slot should extend down 6 3/4-inches from the top edge.

8. Building the carriage back

Cut two l 1/2 x 1 1/2-inch angle clips, 3/4-inch wide. Clamp them together and drill a pilot hole 3/4-inch in from the edge of one of their legs. Cut their other legs back to 3/4-inch long, and round off the corners of the long legs. Center the furnace in the vertical position and pinned at the top of the carriage slots. Attach two vertical angles, toed inward and away from each other on the back wall. Leave 1/8 -inch of space between each vertical angle and the outside of the hinge assembly. Affix one of the angle clips at the top of the hinge slot (see Caption 11-5). Prop the furnace low in the slot so that only it's curved face extends beyond the carriage top. Level the furnace in both directions, then run allthread across both of the side slot's vertical angles below both axles. Drill a through hole in the lower angle clip and use the hinge to

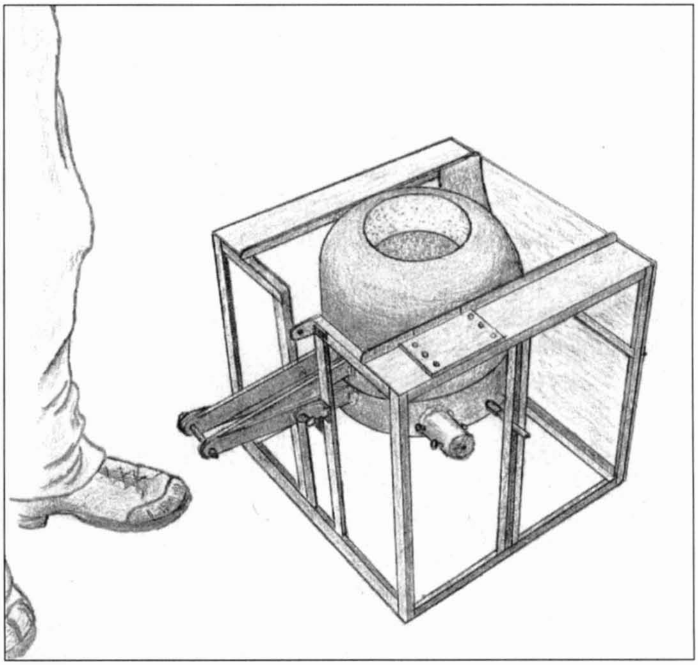


Fig. 11-4 Lowered furnace with hinged front panel on. The upper clip is used to position a pilot hole in the furnace hinge, and then the parts are separated to finish the threaded hole in the flat bar and the through hole in the angle clip. Lifting handle not shown here. This is a bead furnace configuration. With the hinged upper panel locked against the front carriage face and with the rest of the panels installed, the furnace can contain an outer insulating layer of Perlite. The insulation is drained out, and the upper front panel lowered before configuring the furnace as a glory hole.

position it. Attach a crossing angle beneath the hinge, toed in and down.

9. Installing the top panels and bellyband

Support the locked furnace, centered in the horizontal position. Clamp a top angle on ether side of it about 1/8-inch away from its sides, toed up and out. Cut the angles' horizontal legs short of the end angles so that they sit even with the rest of the top surface. Swing the furnace through a 90° arc, adjusting the angles to maintain a minimum 1/8-inch clearance at all points of the arc and attach them. Cut and sand two sheet metal rectangles long enough to extend from the front carriage face to the back face between the inner and outer angles; for mechanical assembly, fasten the sheet metal first and attach square cut angles over it.

The front of the furnace must be supported when it is in the horizontal position. A sheet metalbelly band is cut 3-inch wide and 3-foot long, then bent halfway around the furnace. You can also trap the bend center and push against the flat ends to adjust its shape. Place the band under the furnace and support them both in a leveled horizontal position while attaching it to the two inside top angles. Cut off the excess and sand the end corners into radiuses. Attach a horizontal angle below the bellyband, toeing in and down.

10. Constructing and mounting the burner collar and cover plate

Read the directions in Chapter 9, Step 6. Compare them with the directions in the fastener-assembled version. Use the appropriate methods from each section to help construct and install the burner collar (remember the dimensions must be changed to fit the chosen burner). The collar installation has been delayed until now in order to make sure the collar also clears the top angle. Once the collar is in place, use it to lay out an opening in the carriage sheet-metal top and inside angle on this side. Leave the outer angle in place. Make a cover plate about 2-inch longer than the opening, drill and thread holes for thumbscrews in the ends to screw the plate in place, then attach the removed angle to the cover for a stiffener. The cover plate can be temporarily removed to allow furnace positioning, keeping the frame strong. Top panels are part of the carriage's structural integrity. All other panels are only needed for a bead furnace or hanger bucket configuration and can be installed at your leisure.

11. Mounting front panels

Sheet metal panels are only needed to contain an insulating layer of Perlite. In that case, start by attaching the lower front panel between the middle and lower horizontal angles. Next, attach a piano hinge at the panel top, and then attach a panel to the hinge that will cover the top half of the carriage front to the top. Install thumbscrews in the top corners. The top panel locks in place to contain Perlite, but swings down and out of the way when the furnace is used as glory hole.

12. Mounting side panels

The side panel opposite of the burner collar is a single panel with an opening to match the axle slot; its bottom is rounded for a close fit around the bottom side of the axle. A cover plate with a half round recess on its bottom end is screwed to the sheet metal panel before Perlite is poured into the carriage. On the burner side, a three-quarter panel is used to cover the bottom half and one upper side from the carriage front to the near side of the slot. It also fits closely around the axle's bottom. An overlapping quarter panel covers the rest of this side. After it is screwed in place lines are projected from the burner collar to the panel, with the furnace in the bottom vertical position. A hole for the burner tube is cut through the panel using these markings to find its center, but matching the outside diameter of the chosen burner at that point. This panel is only used when the carriage is filled with Perlite.

13. Mounting the back panel and cover plate

The back panel is one piece with a square recess for the hinge opening. Once it is installed the furnace is locked in the lowered position and a cover plate is built to seal the opening inside the hinge assembly. The cover is cut as close as possible in the hinge area, but overlaps the opening on both sides above the hinges. Screw it in place when Perlite is used.

14. Making the furnace plug and installing the refractory

Disassemble the furnace, turn the bottom half over and insert the second plastic pudding cup. Proceed to line both shell parts with refractory according to the instructions in Chapter 9, minus the retaining screws. If you are going to melt the higher temp glass formulas, it is best to use straight refractory with no insulation in the mix. After a hard set, push the plastic cup out of the bottom lining with a rod. Reassemble and heat cure the furnace. Afterward, use it to heat cure the plug, setting it on the furnace bottom like a plinth. Make sure the refractory edges meet closely. A high alumina kiln shelf can easily be drilled with a holesaw and retrofitted on the carriage as a glory hole door, but this isn't considered well advised.

15. Additional cart with sliding bottom door

If this furnace is to be used on the cart in Chapter 6 use: a closing cap for the cart's burner portal, a flat bar under one carriage bottom angle, and a metal bucket. These will control the ebb and flow of Perlite that can be inserted through the top cover plate and released into the bucket.

To use the furnace as a separate piece of equipment, build a wheeled cart out of 1 1/2-inch angle, with a bottom shelf that is 2-foot square. Build the top shelf frame 1/8-inch larger than the carriage bottom all the way around. The angles of the top frame toe in and up on three sides, but the fourth side toes down. Run 3/16 x 1/2-inch flat bars along the web (inside corners) of the two side angles from the toed down angle opening to the toed up angle end. Cut 1/8-inch thick sheet metal into a sliding plate fitting within the flat bars and with a protruding handle or ring cut in. Figure the height you want the glory hole opening to set at and cut four vertical angles to make the cart the desired height. If you are screwing everything together, leave extra length and slit both angle ends, so that they can be bent to accommodate the inward sloping cart walls. Install a sheet-metal lower shelf and sheet metal walls on the cart's sides. On one side cut an opening in the middle third of the wall, and screw on a cover plate. Mount the furnace on the cart. Drill pilot holes in four places near the corners and well above the sliding shelf; penetrate both cart and carriage. Drill and thread the four places in the carriage for 1/4-20 thumbscrews, and drill the cart hole out to 5/16-inch for through holes. These four screws lock cart and carriage together. The addition of a cover plate over a release hole that is centered in the carriage's bottom plate, allows a tub to catch the Perlite. But, this system is not as elegant as sidewalls on the cart.

12

Brazing

Brazing and soldering

When two metals are joined together at their melting point, with or without filler metal, the process is called welding. When two metals are joined together below their melting point, but above 840°F with the aid of a filler metal, the process is called brazing. Below 840°F the process is called soldering. However, in common practice silver brazing is usually called silver soldering. This is because of the whetting action of this kind of brazing alloy, which gives it a narrow elastic range and the tendency to run like water when hot enough. The way it handles is what distinguishes silver soldering (technically silver brazing) from hard brazing methods, which are practiced in a fashion more consistent with torch welding. If you buy the filler rod from a welding supply, ask for silver braze—at a jeweler's supplier ask for silver solder. Do not buy so called "silver solder" from a hardware store. This is low temperature plumbing solder, and is not fit for use with any of the equipment in the book.

Silver brazing basics

Molten metals solidify around crystalline structures upon cooling from the liquid state. As metals are heated into the red range, their crystals start moving apart, leaving open spaces, which hard solders can penetrate. When the parent metals and solder re-solidify together, their surfaces are intermingled. This creates a far stronger bond than soft solders (common plumbing solders), which can only adhere to the metal surface. This is because they flow at about one third the heat needed to open the crystal lattices in most metals.

Silver brazes (hard solders) are essentially alloys of silver, copper, and zinc. The zinc content allows the solder to flow more easily than an alloy composed of only silver and copper could. The proportion of zinc also controls their melting points. Hard silver solder is about three percent zinc and melts at 1490°F. Medium silver solder has about ten percent zinc and melts at 1390°F. "Easy Flo" (the pipe fitters favorite) has about fifteen percent, and melts at 1270°F. Try to use "Easy Flo" for your soldering needs, but if the welding supply store isn't willing to sell small amounts of silver braze, try a jeweler's supplier.

Some important facts to remember are:

(1) The joint to be soldered needs to be clean of dirt, oils, and paint. Once heated, these substances become carbon. Carbon and solders don't mix. This fact can be used to protect places like thread where you don't wish the solder to flow. Use paint thinner or alcohol on the parts to make sure that not even a fingerprint remains.

Completely smooth surfaces do not support capillary action as well as slightly roughened surfaces. Solder flows better over sanded parts.

(2) The oxide layer must be removed from the parts. The joint must be fluxed to prevent it from absorbing oxygen when heated. During heating oxygen will rapidly form a new oxide layer on unprotected metal surfaces. Metal oxides melt at much higher temperatures than their parent metals.

(3) Close fitting parts make stronger joints than loose fitting parts. Sloppy joints will also use up a lot of solder.

(4) Solder always flows toward the heat even when that direction is uphill. If you have an oxy-fuel torch with a pinpoint flame, this can be used to manipulate the flow of solder. Otherwise, your best policy is to heat all of the parts evenly to red before applying the solder.

(5) The safest flux is a white paste made of borax and water. When the joint is first heated, keep the torch flame further from the parts to give the water content time in which to boil off (at 212°F). Afterward the flux turns from white paste to a white puffy powder (about 600°F), then milky (about 800°F), and then clear (at 1100°F), which gives an excellent warning that you are near brazing temperature. Watch for this process to complete itself first, then move the flame closer and heat the metal up to dark red heat. By this time, the flux is beginning to turn to a black glass and you should solder before it turns completely black.

(6) Overheating the parts or the solder burns some of the zinc content out of the silver alloy. This can leave a porous joint that may leak gas. Each time the parts are reheated more zinc is lost. On the other hand, under heating the parts can cause the solder to ball up or to only partially adhere to the joint, necessitating a second heat. Prepare the parts carefully, heat them evenly to red heat, and then apply the solder just once.

(7) When brazing, you are heating the parts out in the open air instead of in a controlled environment like a forge or furnace. So, even with a neutral flame oxygen rich ambient air can be drawn over the parts by being pulled along behind the stream of superheated gas from the torch. By choking the torch down to a reducing flame, you will tend to burn oxygen out of this current of air. Also the reducing flame will have a much lower velocity so that it isn't pulling as much ambient air in its wake. The downside to this trick is the fact that reducing flames give off carbon monoxide. On the other hand, fumes from burning zinc are also unhealthy. Only use this technique when you must and only perform it with plenty of ventilation.

(8) Let the parts cool completely before touching them. It is easy to misjudge when the solder solidifies. The parts will cool within just a few minutes. If you're not familiar with soldering, wait to make sure.

(9) Clean up the parts immediately. The new oxide layer will combine with the flux acids on the parts surfaces, corroding them within a few hours.

(10) Think safety.

Avoiding fumes

Work in a well-ventilated area; use a fan if needed. Thoroughly clean the metal parts.

Make sure to grind away any zinc layer from the metal surface for at least two inches on either side of the joint. Avoid fillers that use cadmium. Use only low fuming filler rod. Read the MSDS warning for the filler rod and follow any safety procedures indicated.

Brazing

Silver brazing alloys (also known as silver solders) are extremely fluid above their melting points and tend to flow in the direction from which heat is applied. The amount of zinc in the solder affects its whetting action (its ability to spread over a surface). So, when bridging a gap it is advisable to change from high zinc content, like Easy Flo, to low zinc content like 3% high temperature solder. Even then, you will need very close tolerances in the joint. For the kind of fabrication that would usually be done with a weld change to hard brazing rod.

Preparation

As with soldering, it is vital to have a clean joint area. The degreasing and the removal of oxide films from the surface of the parts cannot be over-stressed. Give the brazing material a clean roughened surface to flow over.

Between two and five thousandths of and inch is the ideal gap for brazing, but gaps of 1/4-inch can be bridged if you have the skill and the patience. Remember to keep your joint as close as you can, but there are more ways to aid the process than just switching to regular brazing rod with a longer elastic range.

You can use ceramic refractory as a physical backing surface to help retain the liquid flow of the filler. Pieces of the high alumina kiln shelf are excellent for this purpose, but you must not try to use the refractory blanket. When the flux is heated to working temperatures it becomes a super acid that will drop through the spun fibers as though they were butter. It attacks the solid surface of the kiln shelf only very slowly. Use thinner or alcohol to wipe the refractory clean of dust. To hold the refractory in place, you can use tinfoil with an adhesive or prop the material up to the joint's underside with the aid of wire to hold in place whatever support structure you cobble together.

When and where to apply the flux

Ideally the flux should be applied just before brazing. It is usually brushed on and applied liberally to the whole joint area. This includes the far side of the joint before placing a back up material against it. The longer the amount of time you are heating, the more flux you should use. It is a common mistake to use too little flux, but it is not possible to use too much of it.

Uniform heating

When heating large assemblies like the burner collar to the forge shell in Chapter 5, it isn't practical to heat the whole area of the parts to be joined. Just heat a broad area around the joint. Depend less on watching the color of the heated parts and pay more attention to the state of the flux. The parts to be joined should be heated uniformly at the joint areas. Direct the heat more towards the heavy part when brazing thick to thin cross-sections.

If you are heating a broad area, the forge burner may work better than a regular oxy-fuel torch. Brazing steel parts is going to be different from silver soldering the brass and copper parts of the accelerators. It is not just a matter of the two dissimilar processes. Steel retains heat longer than copper base alloys. This is an advantage for brazing limited areas of a joint at a time, but you must guard more closely against over heating. Use the flux as your indicator.

With a longer elastic range and a smaller working heat zone, you will find it possible to form something like a weld bead in places. In other places, you may just daub the filler rod on the heated surface and use capillary action (whetting) to accomplish your goal. Don't hesitate to position and reposition the work piece to your best advantage. Don't hesitate to cool the parts and restart the process in several areas and then flow the deposits together afterward. If you get a lump of cold lap, discontinue brazing, cool the parts, grind out the bad section, clean and flux it, and then start over.

Cooling time

Don't forget to give enough cooling time, especially with larger parts. Cooling time can be reduced by the use of water soaked rags or compressed air (do not forget your eye protection). Don't feel nervous about getting water on the parts. It steams off quickly enough. Remember the flux has water in it to start with. Also, the water helps to remove the spent flux, this is desirable both during a pause between heats and necessary afterward, because the flux is corrosive. The flux should be removed with a hot water rinse and a little scouring. If you use too little flux or if you badly overheat the parts, it can be difficult to remove. The simplest method will be to abrade it with the sanding disk.

What filler rod to choose

There are two kinds of filler rod sold today. One is for TIG welding and the other for gas welding. You can't use TIG rod. Buy brazing rod with as great an elastic range as possible (the temperature range between liquid and solid states. You have to choose filler rod that is meant for ferrous metals. You want low fuming non-cadmium bearing rod. Choose a 1/16-inch rod size and get a flux-coated rod. Chances are you won't be given choices as to specific brand or particular number types at your local welding supply store.

Make a practice run first

Buy or saw two pieces of black pipe about one inch wide. Sand the outside and one edge on each pipe. Set them about 1/8-inch apart on a steel table or in a vice. If on a table, trap them to keep them from rolling.

Liberally spread borax paste on them and slowly heat them up with your burner. When they reach orange heat, move your filler rod onto one of the pipe edges. Tip upward from the horizontal position and on the bottom side (downhill side) of the flame. Withdraw the rod as soon a little lump of it melts off. Now, concentrate on heating the lump until it fully melts and relaxes into the gap between the two pipes. As soon as this happens, melt another daub off of the filler rod. You will note that the capillary action is strong enough to hold the brazing alloy suspended between the two pipes. Continue downhill as far as you can this way, which will likely be about 1 1/2-inches before the weight of the material starts to drag the whole bead down the pipe toward the bottom. At this point cut off the flame and wait for the parts to cool, then wait some more. You're used to how fast copper alloys cool by now. Steel is going to be slower. When the fill is solid cool the parts in water. This helps clean the parts for the next heat. If this is your first time, you might to be feeling discouraged at this point. Don't be; after the water cleans it your joint is going to look a lot better. Pry the other side of the cold joint open, widening the gap to 3/16-inch. Place this side face up on the table and repeat the whole process.

You now have two sides filled in and two sides open. Repeat the process on both of these sides, always moving downhill. Be careful to take the time to fully melt the end of the bead before moving on down the pipes. Take the time to fully melt the beginning of the previous bead when you encounter it at the end of the third and fourth beads.

Clean the parts and have a look. Know that any lumps on the topside of the joint can be ground flat after all hot work is done. Remember that any little holes can easily be filled in with silver solder. Finally, realize that the vertical position, you just brazed in is about twice as hard to do as brazing the burner collar, running downhill, from the horizontal position. If you are still feeling less than confident, remember that both the brazing rod and the fuel are inexpensive. You can practice half a day for about $10.

When you do the burner collar, start at about 1-inch up from the bottom (lowest area) of the joint, and run the bead downhill and then do the same thing on the other side of the circle. Move back and forth, always running downhill (in welding this is known as down-hand) towards an existing braze (known as back-stepping). Moving from one side to the other and back again eliminates "draw" in one direction (the tendency of the parts to move out of alignment, caused by contraction as the heated areas cool). You must watch for draw in the other direction. You can bend the parts back into position if needed after the heat. Each additional brazed section becomes harder to move; they also become increasingly unlikely to need it.

Chapters Notes

Chapter 1, Safety

(1) Use soap containing the foaming agent Lauryl Sulfate; dish washing liquid or shampoo makes a good choice.

(2) Keyed chucks need to be evenly tightened. Close the chuck on the drill bit by hand until it is snug, and then turn the key in a chuck hole until it becomes snug. Revolve the chuck, and repeat the process in the second hole, and then the third hole. Continue tightening in this manner until the key cannot move anymore. Don't use a hammer on the chuck key or over tighten in one hole. That will not tighten the chuck as well as the proper method and is likely to end with a shattered chuck jaw.

Chapter 2, The Burner System and Its Fuel

(1) All regulators are unidirectional. On shop regulators there is no opportunity for confusion, but propane regulators are marked for flow direction because their entrance and exit ports look alike. Although this type of regulator is heartier than a shop regulator, it must be sheltered from rain and snow. Large tanks shelter their regulators from direct exposure to weather under a cowling. DOT cylinders should sit beneath an overhang, or the regulator should be covered with a tarp to protect it from snow and rain. Otherwise water may enter through its air vents form ice in cold weather and lock it up.

(2) The flared fitting on LPG appliance hose is an industry standard. A 3/8-inch female flare nut is commonly used on at least one end of the hose; the other end might have a flared fitting or NPT. LPG hose is also found with left-handed fuel nuts (often called an acetylene nut). Torch leads use the 9/16-inch left-hand thread connections for fuel gases in order to prevent oxygen and fuel lines from being cross connected. Naturally aspirated burners have no oxygen line to worry about. Left-handed nuts have to be used for the hand torch whip. The flared nut configuration is better everywhere else, because it automatically prevents the line from accidentally being hooked up to an acetylene or MAPP cylinder. If you have a standard shop fuel regulator you must use the left-hand nut. This is another reason to choose a good quality LPG regulator if you can.

(3) The connector shown is designed for easy construction and makes a good torch handle. Shorter versions can be constructed, but they are more difficult to solder. A 3/16-inch hose barb used in 5/16-inch refrigeration pipe will make a half size version. If one side is cut out of the fuel hose connector fitting and a pocket is drilled for the 5/16-inch refrigeration tube, a fitting barely larger than the 9/16-18 LH thread to 1/4 MPT outlet bushing can be made.

Chapter 3, Building the 1/2-inch Burner

(1) How can a 1/8-inch pipe actually be almost 5/16inch? Its outside dimensions specify the nominal or callout size of today's pipe. This enables the fittings and pipe from one manufacturer to work with those from another (just as threading is standardized for the same reason). Originally, a 1/8-inch pipe was 1/8-inch inside and had a thicker wall than today's materials require for meeting strength standards (minimum amount of pressure required to burst the pipe). Stronger materials allowed thinner walls cutting the weight and expense of piping. But, in order for the newer pipe to work with existing pipe the outside dimensions

were kept and its interior was allowed to grow larger. This also increased its structural integrity and flow rate. So, today we have pipe that can be much larger than its call-out size.
(2) # 316 stainless steel is better than CRS because of its higher chrome content; but CRS is better than plain mild steel. You can use black wall #40 steel pipe if no SS tube is available. If you are forced to use the pipe instead of the SS tube, you must also file down the bulge of its interior weld seam. Note that black wall (plain mild steel) pipe will rapidly oxidize away when employed as a burner nozzle, unless it has a protective coating (See Resources).
(3) If you are using pipe or # 40 tubing you can employ a threaded hole for the thumbscrew. It will then bind against the burner tube wall to lock the choke sleeve in position. Thin wall tubing requires a slot because there isn't sufficient thickness to hold a thread. In place of the galvanized pipe, you can use any metal tubing with an inside diameter that permits it to slide freely on the 7/8-inch outside diameter of the 1/2-inch pipe nipple. Mild steel and stainless tubing are easily found in salvage yards if you take the sanded burner tube to one for a quick comparison. You can also use copper doubling pipe for the choke sleeve. This is convenient if you wish to add the advanced options later. The doubling tube is a slightly oversized copper pipe, which is designed to be slipped over ruptured 1/2-inch copper tube for in-place plumbing repairs. It comes in one-foot sections, and can be found at larger hardware stores (see Resources). You can cold form the flare on copper tubing. Both steel tubing and the copper doubling pipe are larger than the outside diameter of the burner tube. This will greatly reduce your sanding work, but makes a looser fit than can be achieved with the galvanized pipe. You must still remove the black varnish from the burner tube.

You can also purchase a flared nozzle already made and use it for the choke. To do so, add a spacer (part #1B), as you did for the nozzle, then drill and tap a 1/4 x 20 threaded hole through them both for a thumbscrew (see Resources list for flared nozzles). Simply grinding out the inside of the back edge on the plain choke will give almost as large a jump in performance as creating a flare on the hand torch, although the performance difference shows up plainly when the burner is used in a forge or furnace.
(4) The 1/4 x #20 thumbscrew is used because this size is needed for the burner collar of the forge. A single thumbscrew size saves money spent on drills and taps. However, a smaller thumbscrew (say size #10) will allow a narrower slot in the choke sleeve. This will ease tolerances on the rib sizing. Using the thumbscrew in a threaded hole on the choke sleeve isn't recommended because the sleeve must be made a little longer this way to insure that the screw is kept clear of the air intakes. This extra length would shorten the distance available for clearance between the fully opened choke and the burner nozzle. The hand burner would not fit properly within the forge in Chapter 5 or the furnace in Chapter 9 in that case. If this is of no importance, than the slot becomes a lot of extra work for no advantage.
(5) If you use Tweco tips the part is #14T-23 for .023-inch wire size, or #1140-1300 for .6mm wire size. If you have a problem obtaining the right MIG contact tip, use any 1 1/2-inch long tip for .023-inch or 6mm wire. If you use a different tip, remember to adjust the drill and tap measurements to it. You can taper the tip afterwards. Do not use a short tip, as it will not provide sufficient gas acceleration.
(6) Stainless steel setscrews are recommended. This is especially true on the burner nozzle.
(7) 1/2-inch x 1/2-inch steel angle is best, but you could use angle as large as 1-inch x 1-inch.
(8) You can probably get your hardware store or salvage yard to do the cutting for a small fee

if you make up a cut list in advance.
(9) Shows letter drill size "N" which can be replaced by a 19/64-inch or 7.5406mm drill bit. Letter size "Z" can be replaced by a 27/64-inch or a 10.5mm drill bit.
(10) 1-inch brass or SS brush that is for cleaning brass parts before silver soldering. It is often called a "tooth brush."

Moving A Hot Nozzle: this is easy to do if you leave the setscrews loose and place the short leg of the Allen wrench in one of the screws. Practice running the nozzle back and forth with it before lighting the torch. Once you are satisfied with the nozzle position, tighten the screw. Best practice is to tighten setscrews with the nozzle warmed up in any case.

Judging Flame Heat: a simple performance test can be very useful while you are becoming familiar with different flame characteristics. Simply clamp a small steel flat bar or an old bolt in the vertical position. Heat it with the burner and observe what color it can reach, and then let it cool. Reheat it and record how long it takes to reach its highest heat. Be sure to keep the primary flame about 1/2-inch away from the steel surface. Thus a comparison check will enable you to know where the burner runs hottest, and it can help you to check your understanding of the flame descriptions.

Using SS setscrews allows you a certain grace period before the screws size up in their holes. But, in a few hours of use, this will happen even with stainless screws. Once it does they must be drilled out to be removed. #304 SS is almost as soft as brass and with a little care the screws can be drilled out with an under size bit. The nozzle can be tapped off the burner's end and the holes can be re-threaded.

Galvanizing: zinc has replaced cadmium on most galvanized pipe. This is also holds true for nuts and bolts. Since both finishes can be rough looking color is the best hint as to which metal you're seeing. Zinc plating looks bright (chrome like) when it is new. It may or may not have a bluish tint at this point. As the coating ages it quickly dulls and the bluish tint emerges. Cadmium leaves a coating that rapidly becomes dull gray, looking much like lead. Zinc is far less toxic than cadmium. Do not use cadmium-coated pipe for these burner–not under any circumstances. When in doubt, ask before you purchase the pipe.

Chapter 4, Building the 3/4-inch Burner

(1) 1 1/4-inch ID #316 SS tube 2 1/2-inches long; you can use CRSS but # 316 is better. 1 5/16-inch can also be used and will slightly increase performance while reducing the fitting work. Do not use SS pipe instead of tube, the ID will be 1 3/8-inch. This difference will force you to change the burner collar size on the forge. Furthermore, the inside diameter of the pipe is too large to give good performance on this burner. If you can't find the right size SS tube, order a tapered or flared SS nozzle (Resources list).
(2) 1-inch sc. # 40 galvanized pipe 1-inch long. The spacer is going to need grinding to fit between the 3/4-inch pipe and 11/4-inch SS tube. Galvanized pipe is thinner than black wall pipe. This keeps the work down to a reasonable minimum.
(3) This item is the choke sleeve. Read the flared choke section (Advanced Options of Chapter 3) and the reference to choke sleeves in the Chapter 3 notes. The sizes are larger, but the rest of the advice applies. Also, you can order an SS flared nozzle (see Resources) instead of flaring your own material. The flared nozzle is a good size and shape. Put a threaded hole or slot into it for the 1/4 x 20 thumbscrew, and grind out the interior of the flared end's lip.

(4) 1/8-inch NPT x 3/4 -inch NPT bell reducer. This part can be replaced by a number of substitutes. On the main drawing of the advanced burner in Chapter 3, you will see parts #4B, and #19. Using them as alternates is described in the Shopping for Parts section.
(5) Tweco 1 1/2-inch long MIG welding contact tip for .030-inch or .8mm welding wire. Its threads are 1/4 x 28. If your welding supply store has problems finding this part, buy any 1 1/2-inch long contact tip for .030-inch or .8mm wire size, and reajust the tap size to suit its threads. The contact tip can be tapered later.
(6) Because the 1/4-inch ball valve is larger than the 1/8-inch size, it will have a larger handle, and a stronger valve stem. The valve will be mounted on a steel plate later, and its physical differences will be needed (see Single Ball Valve Idler Assembly in Chapter 5).
(7) There is an extensive discussion of this part in the fittings section of Chapter 2. It is used with the "whip" in order to employ small fuel hoses, but the main fuel hose in any heating equipment should be the standard appliance fitting. This avoids the possibility of a mix-up in fuel gasses (see Acetylene in Glossary).
(8) 1/4–27 F x 1/8-M reducing sleeve. This is a common lamp fitting; you can use the threaded end of the MIG contact tip to search for the right lamp fitting. The right part will allow the contact tip to thread about one-half turn before starting to tighten up. All the other sizes are far too small or too large to be confused with it. Remember that there is a one thread per inch difference in the two parts but they both have the same ID. Next, use the lamp part to make sure you are buying the right size pipe nipple. The lamp part will be only a little too large for the right size and will be to small for the wrong size, which is the next size up. The 1/8-M outside thread allows this part to screw into1/8 IPS (pipe thread) parts.
(9) The 3/8-inch drill can be used with larger bits by purchasing step down drill bits. A drill press will speed up the work. Harbor Freight sells inexpensive bench models (see Resources).

Chapter 5, A Propane Bottle Forge

(1) 1 1/2-inch ID pipe, 3-inch long. This will become the burner collar. If you don't wish to weld or braze on this project you can exchange this part for a pipe nipple and cut off a 4-inch long threaded section. Add a locking nut and sheet metal screws in order to affix the collar to the forge shell. See alternate construction options at the end of the chapter.
(2) One-inch thick ceramic fiber blanket is installed in two layers. The inner layer should be 2600°F or 2700°F rated if you can obtain it, but 2300°F will serve. The outer layer can be 2300°F or 2400°F rated without worry. This means that if you should decide to use one layer of two-inch thick material, it would best be 2600°F or 2700°F temperature rated. However, this is a forge; it shouldn't be run as hot as a furnace anyway, so use the blanket that comes to hand.
(3) Although Sairset is recommended because of its toughness and low price, you can substitute AP Green's Satanite, a high alumina mortar mix that is good to 3200°F for use as a sealant and for the slurry. Many bonding mortars will work for this purpose.

The main traits to look for are toughness and good adhesion.

(4) Parts and kits are available from Jay Hayes (see Resources).

(5) Your fuel cylinder must be kept outside. If you are working indoors, piping or a longer hose is going to be needed. All the parts can be found in the Resources.

(6) 1/4-inch x 1/2-inch steel flat bar 5-feet long: This is recommended for the door parts. If you use a horseshoe this amount would reduce to 2-feet.

(7) This is only needed for welding or brazing parts onto the forge shell. Ignore item sixteen if you are going to bolt the parts together

(8) Four 7/16-inch carriage bolts and coupling nuts. If you are going to bolt the nuts to the forge body, then add four short (full thread) bolts to hold them. You will also need to drill 7/16-inch holes or enlarge smaller holes with a counter sink. The Kiln Shelf is a high alumina kiln shelf 6-inches wide by 16-inches long. It must be at least 1/2-inch thick, and not more than 3/4-inch. You will need to get a 1/2-inch x 12-inch x 16-inch shelf cut lengthwise, or cut it yourself from a standard size; use a thin grinder blade. The high alumina kiln shelf in the PT forge is well supported. It works better than a heavier shelf because high thermal mass (the primary reason for thick kiln shelves) and is counterproductive with the new burners. They operate at about a third more heat output then induced burners. This is enough heat to super excite the ITC #100 IR reflector. It then becomes incandescent and radiates the heat back into the forge interior. Between the improved burners and this reflective coating thermal mass becomes irrelevant in this forge.

(9) Hole saws come in three grades. The wood-working grade cannot be used at all. The soft steel cutting grade should be run at the proper speed, which is lower than your drill is likely to turn. Stainless and hardened steel grade is the best choice to use if you can find it.

(10) The saw work can be done with a thin disk on the grinder, but not easily by the inexperienced.

(11) A welding machine is helpful, but not necessary. If you have built the 3/4-inch burner already, you can use it to braze your parts together where necessary, or bolt your parts together.

(12) Using a 4 1/2-inch grinder to cut the end openings Draw a thick line with the ink marker, running just inside the scribed line and touching it. Place the tank on the floor, and fill it with water up to the beginning of the top curve. The water is needed for its stabilizing weight as much as for fire protection. Sit on a five-gallon bucket or low stool while grinding. Brace the grinder as recommended in Chapter 1, and hold it at a low angle to the tank face (about 45° up from horizontal), use the edge of the blade to cut a triangular groove in the metal. Start grinding at the inside edge of the inked line and let the grinder drift down to the outside edge. As you grind your "trench", keep moving the blade from side to side along the curved line. Do not try to grind completely through the material. Do the curved line first. When you grind the straight line at the bottom of the opening, bring the grinder up near to a right angle, but keep moving it back and forth along the line. You do not want to grind completely through the material yet. Keep moving around the curved line and down the straight line until you start to break through the metal. At this point you can take

the safer path of finishing the cut with a regular saw. If you continue grinding, remember to brace yourself against "kick back" and move the grinder back and forth as insurance against dropping the blade too deeply into the cut. Do not attempt to finish grind all the way to the corners of the bottom line. When the face begins to become loose, stop grinding and bend the weakened section down with a hammer, then use blows on its exposed edge to break it off. Do not attempt to bend it back and forth to break it; the parts will have razor sharp knife-edges in some places. Change to the sanding disk and smooth the opening's edges. Grinding the second opening this way calls for clamping the tank firmly. Any attempt to grind the second opening without the tank secured will end with the grinder binding in the cut as described in Chapter 1.

(13) If it doesn't fit through the hole, grind the end to match the shell's curve and place the collar on the outside of the shell. You will have to use the aiming method when you do this because the collar sits at a slightly inclined angle to the shell.

(14) Rigidizers usually consist of colloidal silica or colloidal alumina suspended in water. The silica solutions normally have food coloring added. Silica presents a danger from particulate, when dry and unfired. The main hazard to watch for with silica rigidizers is the addition of Ethylene Glycol. EG, sometimes added to rigidizer as an antifreeze when it is shipped during winter months, is an odorless and colorless toxin. Because it is difficult to determine the presence of EG, protective gloves should be worn when handling rigidizer, and the rigidized fiber should only be heat cured outdoors.

Chapter 6, Building a Forge Cart

(1) If you desire other colors in the heated area, use engine paint.

(2) Insulating refractory bricks are used instead of castable or rammable ceramic, because the heat curing cycle for refractory mixes makes them tricky to use in some structures. Refractory bricks can be held together with air setting refractory mortar, and will be just as effective.

(3) Pearlite is used as filler material in concrete block walls, a soil additive for greenhouse mixes, and as attic insulation among other uses. The point is that this material is inexpensive. Find a large bag of it at someplace like Home Depot

(4) A short nipple (2-inch pipe), two close nuts, and a pipe cap can be substituted as a burner collar. However, the 3/4-inch burner will have to be lengthened two inches.

(5) The 2-foot carpenter's square is more likely than any other kind to be inaccurate. Check the square's accuracy by comparing several of them to each other (place one square inside another and then reverse their positions) when you find three that mate up properly, choose one of them. You can also check the square by using "3-4-5" Any multiple of three (3x 5 or fifteen inches) on one leg, and the same multiple of 4 (twenty inches) will give a multiple of 5 (twenty-five inches) when read diagonally between the two points (15 and 20) if the square is accurate. This same method can be used to check the cart without employing a large square.

Chapter 7, 1-inch Furnace Burner

(1) 1 1/4-inch sc. #40 pipe makes a very loose fit. This is more of an aggravation than

a problem. It can be overcome by having this part cut on a pipe cutting machine, rather than sawed. The machine will leave an internal lip, which can be filed to a perfect sliding fit (half round file). Tubing comes in sizes that will allow this choke to be made the same way previous versions were. A can of heat resistant spray paint can used to replace the black lacquer coating, which must be removed. It can be sprayed into the choke sleeve as well as on the burner tube's exterior in multiple coats to improve the fit.

(2) Either an air or electrical die grinder with a 1/8-inch carbide cylindrical file will quickly rough out the bevels, or the square file can just be used to smooth the finished surfaces. An inexpensive import model works fine. Rubber dishwashing gloves, tightly woven clothes, eye protection, and immediate personal as well as area clean up will help to keep the needle sharp burrs from ending up in your skin

Chapter 8, 1 1/4 Furnace and Kiln Burner

(1) If this burner is going to be run for long periods within a furnace or kiln, and you cannot find heavy wall SS tube, than a cast refractory burner port is recommended.

(2) Galvanized pipe is used in order to reduce the amount of work needed to achieve a sliding fit. There are also SS and mild steel tubing with slightly larger ID if you have a salvage yard in your area. Even black wall pipe can be made to serve, but since ID of larger pipes varies your sanding work could be considerable.

(3) The sc. #80 pipe nipple is almost certain to be a special order part (see Resources). Heavy wall pipe or tubing would also probably need to be special ordered. If you can find a local source for heavy wall pipe or tube with an ID about 3/16-inch, then the outside can almost certainly be threaded with a 1/8 NPT die.

(4) MIG welding contact tips for .045-inch and .052-inch wire size. The .045 tip size orifice is just a little small. You can use torch tip cleaners to slightly enlarge it to a perfect size.

Chapter 9, Foundry Furnaces

(1) One 55-lb. bag of refractory is more than enough to line this furnace. It will take a long time for the fuel savings from using high insulating refractory in the outer layer to repay the investment in a second bag. Therefore a single refractory is recommended for the sake of common sense. By mixing Pearlite with some of the refractory in an outer layer similar benefits to insulating refractory can be obtained without purchasing a second bag. Small bags of Pearlite can be obtained from most garden suppliers. This can be replaced with crushed insulating firebrick for a furnace dedicated to bronze pours. Kaolite 3000°F refractory is preferred for the furnace because it grinds easily.

(2) You can use either a 1/2-inch or 3/4-inch jet ejector burner. You could even use a 1-inch burner by enlarging the burner collar. The biggest difference is in the amount of time the three burners are going to take heating up the furnace. As long as the burner port is built large enough to accommodate the burners, you can change sizes in the order that best suits the project. Their sliding washers will effectively seal the entrance. Thus, you might use a 1-inch burner to rapidly melt a charge of iron, and

then replace it with a 1/2-inch size to melt two grams of gold.

(3) Special multiple size step-drills for sheet metal work are available in most hardware stores. They are very popular with electricians, because they provide exact hole sizes and don't take up a lot of space in the toolbox. The better brands work well, but are very expensive. A steel rated countersink will do the job as long as some extra attention is paid to the hole size as it is reamed out, and it won't cost much more than a drill bit. Choose a counter sink that isn't a lot larger than the finished hole in order to get better visual cues.

(4) The saber saw will be needed for the 5-inch exhaust opening if you don't wish to use the grinder to form it. It will also be needed for the burner collar opening if you don't wish to use a hole saw or do chain drilling.

Chapter 10, Farrier's Forge

(1) This hole saw is covered with brazed carbide particles. If it can't be found, substitute a cheap wood cutting hole saw, and consider it expendable. It will cut through the refractory, but will be ruined in the process.

Chapter 11, Multi-hole Glass Furnace

(1) This amount of sheet metal is only needed for the bead furnace configuration. Otherwise some scrap for the bellyband and top panels can be purchased from a salvage yard.

Glossary

Acetylene (C_2H_2) A colorless highly flammable and explosive gas, with a garlic smell. In its liquid state it is violently explosive and therefore it must be stored as a pressurized gas which is dissolved in acetone, and the acetone held in a container filled with non-reactive materials that act as a buffer against physical shock. When acetylene gas is allowed to form at any pressure over 15 PSIG it can rapidly degrade and form explosive by products (remember, the pressurized acetylene in the tank is dissolved in acetone, but when you draw it from the tank it is not). Opening and closing of an acetylene cylinder's valve should be done slowly to avoid producing shock. Acetylene has the lowest ignition temperature (auto ignition at 581°F) and the highest flammable range (explosive mixtures of between 2 and 80% in air) of any of the commonly used fuel gasses. Only hydrogen is more dangerous. It can form acetylides if it comes into contact with potassium, copper, brass, silver, mercury, or gold. It will also do so with some alloys. Once dry these acetylides are highly shock sensitive and powerful explosives. The copper tips used on acetylene torches are made of special alloy with less than 65% copper in them; the brass parts of an acetylene torch are also made from a special alloy, and silver brazing is done on the side of the parts furthest away from gas contact. Acetylene will form explosive compounds if it comes into contact with nitric acid, and will react violently with chlorine, bromine, iodine, and fluorine (as well as halogen refrigerants). Because it can only be drawn off from the fuel tank very slowly, several tanks must be "ganged" together in a common manifold to get a large flame. It has been used because its primary flame was considered much hotter than any other common fuel gas. This is an arguable point, nowadays. If you could compress all the acetylene found in a typical 132 cubic foot tank down into a liquid, like LPG, you would only have one quart of usable fuel. Even if it were twice as hot as propane, it would still cost about 25 times more to burn. The only wise use for acetylene fuel is in some forms of oxy/acetylene welding where the free carbon is needed rather than problematic: for instance torch welding mild steel or in carbon blacking.

Alumina A fine white powder with a high fusing temperature. Kiln furniture is made of high purity alumina.

Angle A trade term for extruded angular shapes. These two legged 90° forms have their dimensions and positions called out in accordance with an exact terminology describing their shape and dimensions. If you hold your hand out and make a fist, then extend your forefinger and thumb straight out, they would form a sort of "L" shape. Their tips would be similar to the edges of the angle. Angle edges aren't called tips, however—they are called "toes." If you did this with both hands at the same time your thumbs would be pointing at each other. With angles, this is called "toed in." Both of your fingers would be pointing straight up. With angles this is called "toed up." Not all angles have equally wide sides (which are called flanges) a typical angle with equal sides might be described as 1/8 x 2 x 2, meaning that the flanges are an eighth of an inch thick and each side (or flange) is two inches wide. 1/8 x 2 x 3 means that one flange is two inches wide, and the other flange is three inches wide. Its end would look like a capital "L" So, the long and short lines of the "L" are flanges and their ends are toes. The outside point where the two flanges meet is called the "heel". The inside corner is called the "web".

Annealing (1) Heating steel red hot and slowly cooling it, thus reducing the brittleness and increasing both flexural strength (spring) and malleability (ability to be shaped) of the metal.
(2) The process of stress relieving glass by holding it at about 950° F for a time (soaking), and then very slowly reducing it to room temperature in order to avoid building new stresses during the cooling cycle. Ceramics kilns have slow cooling cycles for similar reasons.

ASME Container A storage tank that is made to American Society of Mechanical Engineers standards. They are permanently fixed in place and filled on site. Their capacities are measured in gallons.

Aspirator (1) A device using fluid velocity effect to produce a low-pressure zone (a venturi).
(2) This term is also used to describe a specific type of venturi burner system, which uses moving air to entrain fuel gas in the same manner that carburetors use air to draw gasoline vapors in small internal combustion engines. Aspirator mixers are employed with very low pressure systems. The burners featured in this book are inspirators—meaning that they use a high velocity fuel gas stream to entrain air. Jet ejector burners are inspirators.

Bagwall One or more baffles placed inside fuel burning kilns to direct the flame path for more even heating around the ware.

BASO valves One of many manufacturers of gas safety valves. Their product became so well known that safety shutoff valves are often called BASO valves, just as locking pliers are called Vice-Grips even when made by some other manufacturer. Note that BASO valves come in low-pressure models for natural gas or low-pressure fan blown systems, but they also come in high-pressure valves for venturi burners. You need the high pressure model with these burners.

Bisque Unglazed ware that has been fired to a temperature just short of vitrification. It has become a permanent ceramic, but its surface is still porous, and takes coatings well.

Batch Molten glass fused from cullet (used glass) or from a mixture of metallic ingredients and sand.

Butane (C4H10) A colorless, odorless, flammable gas with very similar characteristics to propane. Their main differences are their vapor points. Propane will boil at F –43.7 and butane at F 31.1

BTU British thermal unit is the amount of energy required in raising one pound of water one degree Fahrenheit. Liquid propane contains 91,560 BTU's per gallon

Capillary action The principle by which the filler metal is drawn onto the part's surfaces and through a joint. It results from greater adhesion of a liquid to a solid surface overcoming its internal cohesion, and allows a liquid to rise above its natural level (as on a vertical surface).

Carbon Monoxide (CO) An odorless and colorless gas. It effects the central nervous system and can cause death through asphyxiation. Carbon monoxide dissolves into the blood and remains there; it does not metabolize. It has about 200 times more affinity for hemoglobin than oxygen does. Therefore, it readily binds up the hemoglobin preventing any further ability to carry oxygen. It stays in the red blood cells until they are broken down and rebuilt (once every 120 days). The only effective treatment for monoxide poisoning is hyperbaric therapy. The afflicted person is placed into the chamber and it is pressurized until the blood serum can saturate with oxygen. This keeps the person alive until the monoxide-saturated cells can be replaced.

Castable Powdered refractory materials that can be mixed with water and poured into molds.

Celsius This temperature scale is part of the metric system. On this scale pure water freezes at 0 degrees and it boils at 100 degrees. Fahrenheit minus 32 and then times 1.8 gives Celsius.

Ceramics Are a form of (primarily) synthetic material. Glass is a ceramic; as is tungsten carbide. Ceramics commonly withstand high temperatures and corrosive substances. Some are noted for hardness or resistance to abrasion. They can be used for electrical resistance or for superconductivity.

Check Valve Check valves prevent back flow of gasses, for instance, oxygen into a fuel hose or vice versa. They close if a reverse flow starts. They are required by OSHA between hoses and a torch, and can be found other places on fuel gas systems as well.

CFH Cubic feet per hour; the standard volume measurement of moving fluids.

Colloidal These are particles so small that they won't settle in water. Molecular movement is sufficient to hold them suspended.

Combustion Or burning, is the process caused by the rapid combining of chemicals to form new molecular combinations. The energy given off by this process helps to sustain it. Usually a fuel source is combining with oxygen. When this happens in the absence of a catalyst (like heat), it is the slow process known as oxidation. Rust is formed this way. When reactive chemicals combine after ignition, the process is exothermic and a state of combustion will exist as long as fuel and oxygen are provided and the exhaust products can exit from the combustion area. Combustion usually involves the combining of a gas with the oxygen in air. A liquid fuel source is first turned to a vapor (flashpoint). The vapor combines with oxygen in the air and is ignited. Once this happens the heat by-product tears the little clumps of molecules in the vapor apart and the fuel combines even more freely. Combustion is then accelerated, because the mixing of oxygen with the fuel molecules is multiplied. Thorough premixing of air and fuel vapor before ignition will also greatly improve combustion. Gas combustion should be thought of as a controlled continuous explosion.

There is another factor to be considered when burning takes place inside of a forge or furnace. Because of the internal build-up of energy in the interior, heat is being lost from the flame's wave front less rapidly, and because the energy buildup in the interior walls is so extreme they become incandescent. The incandescent walls begin to radiate infrared energy everywhere, including into the interior of the flame itself. The different internal environment creates what is called an "energized thermal reaction." When enough input energy is combined with a well-insulated interior, and especially if an IR reflector coating is used the combustion process is taken to a higher level. This is the reason that your burner needs to be tested outside of the forge or furnace to get an accurate idea of its performance. It is also one of the reasons "suitcase" forges are possible.

Compound Burner The venturi effect is not a strong force in these burners. Using a separate mixing chamber behind the burner tube allows a larger diameter in the mixing chamber, reducing air turbulence, as compared with the narrow confines of the smaller tube burners.

Cristobalite (SiO_2) These respirable dust crystals are part crystalline and part silica. Many clays, refractory materials, and glazes include quartz or substances that will break down into silica. Notably refractory fibers made of alumina and silicon start to form cristobalite upon reaching 1600°F. So, used refracteries are more dangerous than new materials because the cristabolite gives off an increased amount of respirables.

Hazardous Technical Information Services (HTIS) Part of the Department of Defense (DoD) upgraded respirable crystalline silica from the status of "reasonably anticipated" to the status of "known human carcinogen." On May 15, 2000, the National Toxicology Program's Report on Carcinogens (ROC), 9th edition identified these substances as "primarily quartz dust occurring in industrial and occupational settings in the form of fine, breathable particles." It also included coal dust and cristobalite as sources of respirable-size crystalline silica.

Crucible The (usually ceramic) container, which is used to contain molten metal or glass while it is heated in a furnace or kiln.

Cylinder Valve The primary valve on a DOT cylinder. It is used to fill the cylinder, control internal pressure, and purge air and moisture from the cylinder before first fueling. It may contain an internal excess flow valve. All modern cylinder valves have an overfill protection device. Most have a spring-loaded valve that does not allow the gas to flow unless the valve is connected to a fitting, so that an accidental opening of the valve, when the cylinder isn't connected can not cause a leak.

Damper A temporary obstruction (ex. a piece of kiln shelf) that is used to partially or completely close the flue of a kiln.

Expansion Ratio The amount of gas produced by the evaporation of liquid at a given temperature. The expansion ratio of propane is two hundred and seventy to one.

Excess Flow Valve A safety device (check valve). It is designed to close if the fluid passing through it exceeds a predetermined flow rate. A sudden pressure drop can bring this about, from a ruptured hose, etc. Sometimes they are built into the cylinder. Damage to the external valve can't prevent this kind from functioning.

Firebrick A refractory brick used in kiln and furnace construction. The two main types are hard brick and high insulating. The hard brick prices escalate according to the temperature rating.

Flash Back Arrestor A device that limits damage from a flashback by stopping the continuing propagation of the flame front at the point where it's installed. It is usually made of sintered metal or a spring-loaded trap, and is likely to be a part of a check valve.

Flux In ceramics, the term is used for an additive that lowers fusion temperature. In brazing, flux is used to consume oxides and shield metal surfaces from oxygen absorption during heating.

Grog Filler material made from previously fired ceramics, such as crushed firebricks or fired clay. It is added to furnace refractory formulas to increase stability during firing.

Hydrogen (H_2) It is an odorless, colorless, extremely flammable and explosive gas in the presence of oxygen (or air). It is about fourteen times lighter than air. It can ignite (possibly via static electricity) from high-pressure releases in air. Hydrogen can react with some metals (notably carbon steel) making them brittle. Flash point and flammable range in air are irrelevant limits when dealing with hydrogen. Because the molecules are small, leaks are a greater problem than with other fuel gasses. The flame is almost invisible, which can be a further complication. Hydrogen is the hottest burning of all fuel gasses, and it burns clean, leaving only water vapor as a byproduct if properly combusted. Because of its potential importance as a fuel, industry will solve its drawbacks eventually, but it will always be inappropriate for forges and ordinary furnaces; it's just too hot.

Hydrostatic Relief Valve This is the pressure relief valve located in the backside of the filler valve stem on DOT tanks. It is a spring-loaded valve that will be forced open at 250 PSI, in order to keep the tank from rupturing due to excess pressure. The released propane allows the tank's internal pressure to fall, but the vapor released presents a fire hazard. This valve is the reason for many of the safety rules regarding the placement of propane containers.

Inch of Water The pressure required for supporting a water column that is one inch high. 27.68 inches = one PSI.

Kaoboard A lightweight, and rigid refractory board made of high purity alumina/silica fibers.

Kaolin A white clay made from Cornwall pegmatite.

Kaowool A lightweight flexible refractory cloth made of high purity alumina fibers.

Laminar Flow A smooth, unimpeded flow of the air/gas mixture through the burner tube.

Liquefied Petroleum Gas LPG Also known as Low Pressure Gas; it is different types of fuel gasses derived from petroleum refining and separated as liquids from natural gas. They are easily compressed, and are stored under low pressure. Mainly they are propane, butane, and propylene with trace elements. Often gas sold as propane contains some amount of butane and or propylene.

MAPP Gas ($C_3 H_4$) A proprietary fuel gas made by Airgas Inc. It is a stabile liquefied mixture of methylacetylene and propadiene. It has more heat potential then acetylene and isn't sensitive to shock. It can be drawn from the bottle without hindrance because it won't degrade at high pressures. It has the usual flammable range limit in air and the lower burning velocity of most fuel gases (such as propane). This makes it more inclined to burn, rather than explode in air. But, because of its acetylene content it will react with metals and halogens to some extent just as acetylene does (see Acetylene). It has an especially foul odor, which makes very small gas leaks easy to detect. MPS gasses are stabile mixtures of methylacetylene and propadiene combined with other additives; there are over two dozen such gasses marketed. MAPP is the most prominent of them.

Methane (CH_4) Commercial grade natural gas is colorless and odorless (mercaptan is added as an odorizer). It is lighter than air at room temperature. It boils at -260° F and its flash point is –297° F. It has a flammable range in air of 5.3 to 15 percent . It can ignite without a spark at 186°F. Sustained autoignition temperature is 999°F.

Material Safety Data Sheet MSDS This is required by law to be made available for all hazardous materials by their manufacturers and marketers. This is not just important for knowing how to safely handle unfamiliar materials. It is also very handy for making an end run around sales hype. For industrial goods, it is often the equivalent of a list of ingredients on a soup can. For instance, the IR reflection rate of a well-known ceramic sealant just happens to be identical to that of a fairly expensive form of Zirconia. Another far less expensive form of this mineral has a much lower reflection rate. In this case, the seemingly high priced product turns out to be a bargain.

Natural Gas (NG) Commercial grade natural gas is almost pure methane with mercaptan added. It only has traces of other hydrocarbons, etc. Raw Natural gas is a colorless, odorless mixture of hydrocarbon gasses and trace elements. It is about three-quarters methane, mixed with other hydrocarbons such as ethane, propane, and butane (see Methane).

NPT National Pipe Thread is the US standard tapered thread used on pipes and pipe fittings.

Oxidation This term is not to be confused with an oxidizing flame as discussed in Chapter 2. For potters, oxidation refers to a clean atmosphere within the kiln caused by a neutral flame from the burner, by electric heating elements, or by the deliberate introduction of secondary air to provide an oxygen rich environment. Any of these methods tend to give brighter colors to glaze (see Reduction).

Pyrometric cone equivalent PCE A measure of how refractory the ware is. Ware might be fired to cone 6 or cone 10 (see heat work). It is a question of time as well as temperature.

Perlite
Expanded Perlite is a synthetic material, which originates as volcanic glass. It can weigh as little as 2 pounds per cubic foot, is chemically inert, and has excellent insulation value. It should be not be rated beyond 1600° F continuous duty. Fire clay, high alumina cement, and sodium silicate make good binders for it. Pricing varies from about $2.75 per cubic foot and up. Its low cost makes it a good candidate for loose-fill insulation or as an aggregate in refractory .

Propane (99%+ C_3H_8) is a liquefied petroleum product that is used as a gaseous fuel. This considered one of the cooler burning of the fuel gasses. It contains more heat per cubic foot than any of the others listed, but normally releases less of its heat in the primary flame than the other fuel gases.

Propylene (C_3H_6) Flash point: -37C (-35F) CC Auto ignition temperature: 840F Flammable limits in air % by volume from 2.3 to 36 percent. It is a hot burning (about the same as MPS), and stable gas. While it has no reactive problems, it is a suspected carcinogen.

Pyrometer A measuring device consisting of a meter and probe (thermocouple) It is used to measure the very high internal temperatures of kilns. It is also used with furnaces, often being dipped directly into the molten metal contained in a crucible.

Rammable Refractory Refractory in paste or clay form. Available as powdered refractory plastic mixes It is applied and rammed into place.

Reduction A reducing atmosphere is created when unburned fuel is present in the kiln. This can be caused by deliberately choking the burner. Reduction is used to change the color of some glazes.

Refractory Any nonmetallic material, which can withstand high temperatures (and/or corrosion). Yet, most refractories are made from mineral silicates, oxides, or carbides.

Refractory Ceramic Fiber These fibers are formed of alumina with some silicon, extruded under high heat and pressure, and then formed into flexible linings, fiberboard, and fiber bricks. Air is trapped between the fibers, giving it very high insulation values and low weight. These fibers can break down, releasing dangerous airborne particles. This is especially true after the fiber has been heated above 1600° F.

Sairset A wet, high temperature (2300°F), air setting mortar. It makes an excellent ceramic fiber sealant and will bond fiber, brick, and metal. It is made with colloidal silica for adhesion.

Service Valve The main valve on a stationary (ASME jurisdiction) LPG tank. It is used to fill the tank. On a DOT cylinder, this would be called the cylinder valve.

Sodium silicate ($Na4O4Si$) Also known as silicate of soda, water glass; and soluble glass. It is used in colloidal form as a rigidizer or binder for ceramic fiber products. It is also used as the "glue" which holds many ceramics products and refractories together.

Super Compressibility Many gases are more compressible at ordinary temperatures than is indicated by Boyle's Law. LPG like refrigerant gases falls into this category. This trait is what allows economical transport and storage of low cost LPG fuels.

Thermal Shock Ceramic materials are brittle. As long as they expand and contract uniformly this is not a problem. Rapid heating and cooling will cause them to heat unevenly. Stresses build in the ceramic caused by the different amount of expansion and contraction under rapid temperature changes. Usually a ceramic with good thermal shock resistance has some additive to provide a "cushion" to movement. For instance, boron is added to tungsten carbide to make it less brittle. Or a material like cordierite may be added to a refractory to lesson the amount of its thermal expansion. Reactants such as kaolin & steatite can be used to form cordierite in refractories during firing.

Venturi Effect The result caused by the application of Bernoulli's principle, which states that any fluid (gas or liquid) put in motion will lose pressure when speeded up, creating a low-pressure area. This low-pressure area causes air to be entrained as the low pressure gas stream passes through an opening. Aspirator and inspirator burners both employ the venturi effect.

Vermiculite (expanded) It should be not be rated beyond 2100°F continuos duty. Its low cost makes it a good candidate for loose-fill insulation or as an aggregate in refractory where higher temperatures make (lower cost) Perlite unsuitable. Fire clay, high alumina cement, and sodium silicate make good binders for it. Pricing varies from about $4.50 per cubic foot and up. It is lightweight and not reactive.

Vortices Swirling streams of fluid air formed at a boundary (the edge of the air openings). They cause drag by creating low-pressure areas behind the desired direction of motion. If the fluid were a liquid instead of a gas, it would be correct to call them eddies or whirlpools.

Water Column WC A gauge used for very low-pressure readings as with natural gas (see Inch of Water).

Zirconia The impure oxide form Zirconium dioxide (ZrO_2) is used as a refractory material. Its melting point is 4829°F

Resources

The reader should be aware that area codes are changing rapidly in many places because of the vast increase in phone numbers being created by the use of personal computers. If you have trouble connecting to any of the phone numbers given, first try going to the web site and checking to see if the prefix is different there. Even if it is not, check with the operator to see if the area code has been changed.

Aluminum Solder

Divesco Inc.

PO Box 18097 4804 Cricklewood Ln., Charlotte, NC 28218 Tell: 1 (704) 567-9800 or Tell: 1 (801) 705-3460 or Tell: 1 (877) 355-5641 Website: http://divescoinc.com/ A-Lum-Rite (fluxless soldering product). Its melting range is 715° F- 730° F, with a tensile strength of 47,000 PSI. Solders aluminum and many other alloys.

Angle grinder (4 1/2-inch)

Harbor Freight

Catalog # 31309-4VGA 5.5 amp industrial grade grinder, with 5/8"-11 spindle and 7/8" arbor adapter. 10,000 RPM Chicago brand, double insulated. See listing under General tools and supplies.

Armored Fuel Hose

Jay Hayes

See under Forge and Burner Building Supplies. He carries braided stainless steel pigtails.

Books

1958 NAVSHIPS

Foundry publication can often be ordered through used book dealers. A reprint of it is available from Lindsay Publications Inc. P.O. Box 538, Bradley, IL 60915-0538 Tell: 1 (815) 935-5353 Fax: 1 (815) 935-5477 Website: http://www.lindsaybks.com/

New edge of the Anvil

Andrews, Jack, ISBN 1879535092, published by Skipjack Press. Order it direct at http://www.bookmasters.com/skipjack/004.htm or through any of the regular online or physical book dealers. For general Blacksmithing know-how with an emphasis on artistic applications, 256 pages, numerous drawings, charts and photographs.

A Glassblower's Companion

Giberson Jr., Dudley F., ISBN 0-9665713-0-4, published by The Joppa Press, 86 East Joppa Road, Warner, N.H. 03278. Available from Joppa Glassworks, Inc. P.O. Box 202 Warner, N.H. 03278 Tel: 1 (603) 456-3569 Website: http://www.joppaglass.com/ Email: joppaglass@conknet.com A how-to book on constructing glassblowing furnaces, glory holes, annealer ovens, and other specialized glass heating equipment (both gas and electric). It also has a good section on burners and safety systems. There is enough solid technical information here to help the reader build a complete glass studio. Giberson is a very clever and devoted innovator in his field—it shows in his book.

Glass Notes

Halem, Henry, ISBN 1-885663-02-1, published by Franklin Mills Press, P.O. Box 906 Kent, OH 44240-2303 Tel: 1 (330) 673-8632 Fax: 1 (330) 677-2488 Website: http://www.glassnotes.com Email: hhlam@glassnotes.com
A how-to book on constructing glass studio equipment. It is more nuts and bolts oriented than Gaberson's book. In fact these two books are perfect complements for each other. Aside from the instructions on equipment building, both of these books are loaded with background information and technical details that will save you many a hard lesson.

Glass Casting & Moldmaking: Glass Fusing Book Three

Lundstrom, Boyce. ISBN 0-9612282-2-9, publisher: Vitrious Group/Camp Colton, Colton OR 97017 Tell: 1 (503) 824-5775. Fax: (503) 824-2267 E-mail: carlsbad@inetworld.net
This is the third in a series of three books on glass slumping, casting, and general warm-glass how-to. I highly recommend Lundstrom's books.

The Kiln Book

Olsen, Frederick L., ISBN 0-8019-7071-7, published by Krause Publications, Iola, Wisconsin. First published thirty years ago, and updated to keep current. It is solid about the engineering principles and background information so essential to make informed decisions about which design to employ; best overview of the subject.

Boron Nitride

WW Grainger

Part # is 2F127 list is $22.22 for 16 oz aerosol can.
Tel: toll-free: 1-888-361-8649 (from Monday through Friday between 7 a.m. and 7 p.m., CST). They also have stores in most metropolitan areas.
Website: www.grainger.com

Burners

Clay Art Center

See under Refractories and insuation Materials

Rex Price

Website: www.hybridburners.com Email: rprice@hbridburners.com Sells his own hybrid style burners (jet ejectors).

Seattle Pottery Supply
See under Online Information section

Ward Burner Systems
See under Online Information section

Jay Hayes
See under Forge and Burner Building Supplies. Flared nozzles are machine tapered from steel or stainless.

Rex Price
See under Burners. Several sizes of # 316 SS nozzles available.

Burner Nozzles

Larry Zoeller
4312 Lahnna Dr. Louisville, KY 40216, USA (502) 361-0706 Email: zman59@ntr.net
1-inch press formed SS burner nozzles (flared) for 3/4-inch burner tub.

Ceramic Burner Heads

Joppa Glassworks, Inc.
P. O. BOX 202 WARNER, NH 03278
Tel: 1 (603) 456-3569, Fax: 1 (603) 456-2138 Web site: http://www.joppaglass.com/
Email: joppaglass@conknet.com
This is the Giberson ceramic burner head, which is featured in his book. It comes in six different sizes to suit glass studio needs.

Copper Doubling Tube

Prairie Home Products
Tel: (800) 367-1568 to find an outlet near you.

Crucibles for Metal and Glass

Budget Casting Supply
See under Online Information. They carry: Bartley Crucible & Refractory (bilge shaped) clay-graphite crucibles; Vesuvius Tercod (bilge shaped) silicon-carbide; Century (A shaped) silicon-carbide crucibles. Both the selection (over fifty crucibles offered), sizes, and general information given about crucibles make this site a major resource.

Contenti Company.
Tell: 1 (401) 421-4040 or Tell: 1 (800) 343-3364
Website; http://www.contenti.com/products/casting/ 170-801.html
Graphite and silicon carbide Crucibles for melts up to 2500 F. Glazed to resist oxidation. Feature pouring spouts. Sizes: #0000, # 2, # 3, # 4, and #16.
Graphite Crucibles. Maximum oxidation resistance for precious metal melting. Sizes: 30 and100 oz. They also carry numerous melting dishes.
Cutoff Wheels For 4 1/2-inch Angle Grinders

Dyson Precision Ceramics
Dewsbury Works, Low Road, Earlsheaton, Bewsbury, England WF 12 8BU Tel: +44 (01924) 468201 Fax: +44 (01924) 459429
Dyson Precision Ceramics (Brierley Hill Works), Brettell Lane, Brierley Hill, England DY5 3LH Tel: +44 (01384) 78028 Fax: +44 (01384) 481852 Website: http://www.dyson-precision.com/ Email sales@dyson-precision.com
They make glass melting crucibles in sizes from 1 to 200 litres. The pots are available in different shapes and materials to suit most needs. They also make kiln furniture, shelving, and cast furnace parts.

Engineered Ceramics
PO Box 365, Gilberts, Illinois 60136
Toll free: (800) 756-8794 Fax: (847) 428-0158
Website: http://www.engineeredceramics.com/ Email: kathyw@engineeredceramics.com They make foundry crucibles, glass pots, ladle liners, tundishes, spouts nozzles, and refractory. Their online discussion of crucibles alone is worth a trip to their site.

Harbor Freight
See listing under General tools and supplies. Catalog # 4530-3VGA (metal cutting). Catalog # 4531-3VGA (masonry/ceramic cutting).

The Hub Consolidated, Inc.
Tell: 1 (802) 948-2209 Fax: 1 (802) 948-2215 Hours are 8:00am-5:00pm Monday-Friday, EST. Website: http://www.hubglass.com/index.htm Email: info@hubglass.com They carry Laclede Christie crucibles

Ipsen Ceramics
325 John St., P.O. Box 420 Pecatonica, IL 61063
Tel: 1 (815) 239-2385 Fax: 1 (815) 239-2387
Website: http://www.ipsenceramics.com/
Ipsen (and Laclede Christie) are well known for their glass working crucibles. Ipsen makes round bottom crucibles that are designed to reduce the possibility of thermal shock in pot furnaces. They have a catalog of regular pots and can make special crucibles on demand.

Laclede Christie

Tel: 1 (573) 437-2132
Cercon Ceramic Consultants Inc. 486-3422 ask for John Bartel
PO Box 116 Hermann, MO 65041 Tell: 1 (573)
They have a large range of crucibles made of different materials to withstand different glass mixes, and they make several different shapes. They have a catalog or you can consult with Mr. Bartel directly.

Legend, Inc.

140 Manuel St., Reno NV 89502-1158 Tell: 1 (775) 786-3003 Fax: 1 (775) 786-3613
Website; http://www.legend-reno.com/minesupply/m58.htm Email: info@legend-reno.com

Seattle Pottery Supply

See under Online Information.
They carry silicon carbide crucibles (for metals) from size #12 through #20; mullite crucibles (for glass and low temperature metals) in 4 x 3 1/2-inch, 6 x 4 1/2-inch, and 10 x 7 –inch; Fused silica crucibles (glass and glass batch) in 4 3/4 x 10-inch, 5 x 7 3/4–inch, and 9 1/2 x 12-inch.

Vesuvius

Foundry division of Cookson Co., Website: http://www.foundry.vesuvius.com/english/news.asp
Sales Offices:
Vesuvius UK Limited, Sheepbridge Works Sheepbridge Lane Chesterfield Derbyshire, S41 9BS England Tel: (44) 1246451007 Fax: (44) 1246455487
E-mail: uk.foundry@vesuvius.com
Vesuvius USA, 661 Willet Road, Buffalo, NY14218 USA
Tel: 1 (716) 825-7900 Fax: 1 (716) 8250866 Email: usa.foundry@vesuvius.com
Vesuvius Hi-Tech, 6329 Route 21, Alfred Station, NY 14803
Tel: 1 (607) 587-9146 Fax: 1 (607) 587-8770 Email: hi.tech@vesuvius.com
Vesuvius Australia, Unit 1-615 Warrigal Road, Ashburton, Victoria 3147 Australia
Tel: (61) 395695100 Fax: (61) 395683019 E-mail: aust.foundry@vesuvius.com
They make crucibles, special liners, tubes, refractories, and more.

Electrical Heating Elements

Euclid Kilns

See under Online Information.

Kanthal International

Box 502 734 27 Hallstahammar, Sweden.Tell: 46 (220) 21000 Fax: 46 (220) 21166
They produce every form of heating element. Website: http://www.kanthal.com./ E-mail info@kanthal.com

Seattle Pottery Supply
See under Online Information.

Excess Flow Valve

Magne-Flo Excess Flow Valves Limited
Excess House, Alcester Road, Portway, Birmingham, U K B48 7HX Tel. 00 (44) (0) 1564 822383 Fax 00 (44) (0) 1564 824712 Website: enquiries@magne-flo.co.uk The valve remains open at normal flow rates. A sudden decrease in pressure will cause the valve to close and cut off most of the gas supply until it is reset.

Fittings

Fittings and Adapters
fittingsandadapters.com Website: http://www.fittingsandadapters.com/

Jay Hayes
See under Forge and Burner Building Supplies. carries the fuel thread to pipe thread connector and many other fittings.

Mr. Heater Corporation
4560 West 160th Street, Cleveland, OH 44135
Tel: (216) 881-5500 Fax: (216) 881-5870 Website: www.mrheater.com Mr. Heater markets US made propane hoses, fittings and accessories. They carry the standard fittings, and some pretty exotic specialty items at low to reasonable prices. Their website lists thirty different suppliers, and the list is far from exhaustive. You can also send to them for a catalog, and order parts directly from them.

Ward Burner Systems
See under Online Information.

Flame Monitoring Systems

Abel Engineering Co. Inc.
PO Box 198 Kimberton PA 19442 Tell: 1 (610) 827-9137
Meader Equip/ Ransome Mfg., PO Box 12446, Fresno, CA 93777-2446 Tell:1 (209) 485-0979.

Clay Art Center
See under Online Information.

Seattle Pottery Supply
See under Online Information.

Ward Burner Systems

See under Online Information.

Forge and Burner Building Supplies

Jay Hayes, C. J. Products Inc.

100 Christmas Place, Weston, WV 26452

Tel (304) 269-6111 10am to 10pm EST. Email: xmas4lites@earthlink.net He maintains a large stock of all the parts needed to build a gas forge. This includes a verity of different types of ceramic fiber refractory, machined tapered burner nozzles, "real" gas orifices, and ITC-100 in pints. This is more than enough to coat the interior of a small forge. One pint will cover about six square feet.

The number of parts will vary, depending on the number of burners used. If you're not sure of what you'll need just let him know what kind of forge and how many burners you are building; he will work up a parts list for you.

If you want a kit that includes almost everything you'll need to build a forge, Jay has several stock sizes. There is also an inexpensive burner kit and some "Fuel Saver" valve manifold kits to help make forge building easier:

14" OD x 24" long, 3 burner LP gas Forge Kit, with Fuel Saver valve manifold, 3" ceramic fiber liner, super duty floor bricks, ITC-100, LPG regulator, and fuel hose. Sold with or without an #11gauge steel shell. The drilling and tapping of holes in burners and burner supports can also be provided.

12" OD x 24" long, 3 burner LPG forge kit, with Fuel Saver valve manifold, 3" ceramic fiber liner, super duty floor bricks, ITC-100, LPG regulator and fuel hose. Sold with or without #11 gauge steel shell. The drilling and tapping of holes can be provided.

10" OD x 12" long, one burner LPG Mini Forge kit, with Fuel Saver valves, 2' ceramic fiber liner, duty floor bricks, ITC-100, LPG regulator and fuel hose. Sold with or without #11 gauge steel shell. The drilling and tapping of holes can be provided.

Fuel Saver valve manifold kit for a two-burner forge with LPG regulator, gauges, and 5 ft. fuel hose and fittings (burners sold separately

Jay's parts list (please note that many of these parts are for induced burners):
LPG regulator, POL tail piece (pig tail); 5 ft. LPG fuel hose; 3/8-inch MF x 1/4-inch MPT hose adapter fitting; 3/8-inch FPT x 1/4-inch MPT hose adapter fitting; 0-30 PSI pressure gauge; 1/4-inch brass ball valve; 1/4-inch brass needle valve; 1/4-inch brass "T" fitting; 1/4-inch brass elbow; 1/8-inch brass elbow; 1/4-inch x 1 1/2-inch (long) brass pipe nipple; 1/4-inch x 2-inch brass nipple; 1/4-inch x 3-inch brass nipple; 1/4-inch x 4-inch brass nipple; 1/4-inch x 6-inch brass nipple; 3/8-inch compression x 1/4-inch MPT; 1 1/2-inch x 3/4-inch bell reducer (not drilled); 1 1/2-inch x 3/4-inch bell reducer (drilled and tapped); 3/4-inch x 8-inch black steel pipe nipple; Brass Orifices (specify drill size); 1/8-inch x 2 1/2-inch pipe nipple full thread choke plates; 1/8-inch x 27 NPT nuts; 1-inch x 3-inch nozzle with taper (machined steel);

1-inch x 3-inch nozzle with taper (stainless steel); Burner mounting tubes (collars) not drilled; Burner mounting tubes (drilled and tapped).
Ceramic fiber insulation blanket 1-inch thick and rated F 2400.
Ceramic fiber insulation blanket 2-inch thick and rated F 2400.
Ceramic fiber insulation board 1-inch thick and rated F 2700.
Super Duty 1 1/4-inch x 4 1/2-inch x 9-inch bricks
1-inch x 1 1/4-inch X 2-inch IFB support blocks.
Call for current prices and shipping

Fuel Gauges

Aubuchon Hardware

1 (800) 282-4393 mailbox@aubuchon.com Magnetic Propane Gas Level Indicator Item #808652. An exterior strip which attaches magnetically to the cylinder wall.

Worthington Cylinders

Division of Worthington Industries, 1205 Dearborn Drive, Columbus, OH 43085 Tel (614) 438-3210
Website: www.worthingtoncylinders.com/index.html http://www.worthington-cylinders.com/index.html They market a fuel level indicator strip that you can tape onto the outside of your tank. They also market a 20 lb. OPD valve cylinder with built-in full to empty sight gauge You can find their cylinder for sale at Costco stores.

Gas Detectors

CCI Controls

Tel. (800) 5000-CCI Fax (328) 660-1136 Website: mktsls@ccicontrols.com A multitude of different gas detectors with automatic controls.

Seattle Pottery Supply

See under Online Informatio and Home Depot stores market the Nighthawk. Most gas detectors are designed as portable tools for heating system inspections or are CO detectors only. This product warns against both carbon monoxide build-up and propane gas leaks. It is also reasonably priced. There are four different versions of the Nighthawk CO detector. One of their units is AC powered with a battery back up. It detects carbon monoxide as low as 30 PPM. It has a digital readout of CO level, and an 85-decibel alarm that triggers automatically if CO or explosive gas levels become dangerous.

General Tools and Supplies

Tool suppliers are too numerous to list, but you should try Harbor Freight for tooling and parts, first. Most small power tools and hand tools are imported and then sold at American made prices. Harbor Freight's goods are imported and sold at import prices. They have area stores, a web site, and catalogs. Or call toll free 1-800-

423-2567 or fax 1-800-905-5220. Among the many items you can buy at reasonable prices, are wheeled carts, and a 55lb. carbon steel anvil, # 42028-OVGA. If you don't see a needed building item mentioned elsewhere on the sources list (for instance castor wheels) you will find it here. Website: www.harborfreight.com

McLendon Hardware, Inc.

1-888-571-7331 This is the Hardware store that the author uses. Mclendon started out as an old time hardware store and has kept their tradition of being well stocked, and well informed. They now have four area stores and are online. Website: http://www.mclendons.com

McMaster-Carr Supply Co.

Website: http://www.mcmaster.com They have offices in:
Atlanta, GA Tel: (404) 346-7000 Fax: (404) 349-9091
Chicago, IL Tel: (630) 833-0300 Fax: (630) 834-9427
Cleveland, OH Tel: (330) 995-5500 Fax: (330) 995-9600
Los Angeles, CA Tel: (562) 692-5911 Fax: (562) 695-2323
N Y City and Philadelphia area Tel: (732) 329-3200 Fax: (732) 329-3772
They market over 39,000 items. They have an online catalog and a written catalog. Their selection and quality is good. This is reflected in their pricing.

ITC #100

Dempsey's Forge

You can reach a main distributor at anvilfire,com Tel: 1 (434) 283-5671. Website: http://www.anvilfire.com/ sales/ITC/docs/flyer 1.htm

Seattle Pottery Supply

See under Online Information.

Trinity Ceramic Supply

9016 Diplomacy Row Dallas, Texas 75247 Tell: 1 (214) 631-0540 Fax: 1 (214) 637-6463 Website: http://www.trinityceramic.com/
Email: Trinityceramic@sbcglobal.net More than 75 different raw materials by the pound.

Kiln Controller

Omega Engineering, INC.

One Omega Drive Stamford, Connecticut 06907-0047 P.O. Box 4047 Tell:1 (800) 848-4286 or 1 (203) 359-1660 Fax: (203)-359-7700 Website: http://www.omega.com/ppt/pptsc.asp?ref=CN1166&Nav=a04 Email:

Ward Burner Systems

See under Online Information.
http://www.omega.com/literature/emaildir/tempmail.html They have a whole series of high quality controllers for about half the usual prices.

MIG Tips

The 14T Tweco contact tips for welding wire can be bought from welding supply stores. They can also be ordered from Mcmaster-Carr Supply Co. See under General Tools and Supplies.

Metal Sources

Online Metals

1138 West Ewing Seattle, WA 98119 Website: http://www.onlinemetals.com http://Email:sales@onlinemetals.com/ They have a good selection and fair prices. Metal Express.com is the retail Net commerce arm of Metal Express, Metal Express Headquarters is at W22 N2464 Joseph Road Waukesha, WI 53186 Tel: (262) 547-3606 or Fax: (262) 547-3860 Website: http://www.metalexpress.net/ They have many outlets in the east and south.

Small Parts, Inc.

1380 N.W. 58th Court P.O. Box 4650, Miami Lakes, FL 33014-0650 Website: http://www.smallparts.com/ Reasonable prices on small amounts of small diameter tubing and components. They stock small parts and tooling also.

Online Information

Bath Potters Supplies

Website: http://www.bathpotters.demon.co.uk/frames.htm They have good online information including RCF kiln plans, a download catalog, and an online catalog. They have links to excellent technical information and a glaze calculator.

Bullseye

Website: http://www.bullseyeconnection.com/connect.html Good online technical articles, and interesting links.

Budget Casting

Website: http://budgetcastingsupply.com/ Email: paul@budgetcastingsupply.com They have good furnace information, links, and foundry supplies.

Dempseys's Forge

1684 Mitchell Mill Rd., Bladys, VA 2938

1 (434) 283-5671 Website:http://www.anvilfire.com/ Lots of information, and links. If you need more space, delete Small Parts, Inc., the last entry just before online information.

If you still need more room delete the area offices from McmasterCar in the General Tools section:

Atlanta, GA Tel: (404) 346-7000 Fax: (404) 349-9091
Chicago, IL Tel: (630) 833-0300 Fax: (630) 834-9427
Cleveland, OH Tel: (330) 995-5500 Fax: (330) 995-9600
Los Angeles, CA Tel: (562) 692-5911 Fax: (562) 695-2323

Evenheat Kiln

Website: http://www.evenheat-kiln.com/contact/contact.htm Good source of information on both glass and ceramic kilns; good glass links.

Euclid's Kiln and Elements

Website: http://www.euclids.com/ Email: mail@pshcanada.com They are a good source for information on electrical kiln parts.

Glass Line's Link Page

Website: www.glassline.net/links/links.html

Hot Glass Bits

Mike Firth, 1019 Martique, Dallas TX 1445 Tel: 1 (214) 827-7734
Website:http://users.ticnet.com/mikefirth/sitemap.htm
Email: mikefirth@ticnet.com

Seattle Pottery Supply

Website: http://www.seattlepotterysupply.com Email: http://www.seattlepotterysupply.com/email.htm The site is just getting started, but the company is well established. The author shops here. SPS markets their own kilns as well as standard brands. They are very knowledgeable and easy to deal with. Expect excellent technical advice from this source.

Ward Burner Systems

Website: http://www.wardburner.com/ Email: wardburner@aol.com
Large amount of general information on burner systems, and kiln construction.

Organizations

Artists And Blacksmith's Association of North America, Inc.

LeeAnn Mitchell, Central Office Administrator P.O. Box 816, Farmington, GA 30638-0816 Tel: 1 (706) 310-1030 Fax: 1 (706) 769-7147 between 8:30 AM and 4:30 PM, Monday-Friday, EST Website: http://www.abana.org/

The National Ornamental & Miscellaneous Metals Association

532 Forest Pkwy., Suite A, Forest Park, GA 30297 Tel: 1 (404) 363-4009 Fax: 1 (404) 366-1852 Website: http://www.nomma.org/

Pressure Gauges

Technical Specialties, Inc.

30852 Hwy. 181, Spanish Fort, AL 36527 Tel (800) 395-3369 or (251) 626-0100 Fax (251) 626-2703 Website: www.technicalspecialties.net They carry a number of reasonably priced pressure gauges, including three different 0-30 PSI gauges.

Ward Burner Systems

See in online information section.

Quick Connectors

Mr. Heater Corp.

4560 West 160th Street, Cleveland, OH 44135. Tell: 1 (800) 251-0001 Fax: 1 (800) 321- 0502 Website: http://www.mrheater.com/ They have a variety of Gas Quick Connectors to choose from. Most of their fittings are listed in the written catalog (see above). Stock no. F276152 is a 1/4" Male Pipe Thread x 9/16" Left Hand Male Thread fitting. It is sold in lots of six for $2.20 which still costs less than one set of quick connectors from a hardware store. (prices subject to change). Stock no. F276181 is a Quick Connector with its own shutoff valve and excess flow plug (for line breaks) It has 1/4" male pipe threads on both ends, and therefore requires the previously listed part for use.

Burning lead quick connector sets can be found at welding suppliers.

Refractory Blanket Anchors

Bath Potters Supplies

See under Online Information. Bisque buttons, which are built to shelter tie wire from the kiln's heat.

Seattle Pottery Supply

See under Online Information. Ceramic studs rated to 2700 F. They include the anchor, cap, and 6-inch stud. A 4-inch washer is optional. This system is a practical way to suspend very thick layers of insulation, or for use with clamshell forges.

Refractory and Insulation Materials

Clay Art Center

Tel. 1 (800) 952-8030 or 1 (253) 896-3824 M-F, 10-5 EST Website: www.clayartcenter.com Acme Marls kiln shelves (highest quality high-alumina shelves imported from England). They also carry silicon carbide kiln shelves.

Jay Hayes

See under Forge and Burner Building Supplies.

Price Marketing Association

McGills Glass Warehouse 7121 Radford Ave., North Hollywood, CA 91065 Tell: 1 (818) 765-5790 or 1 (800) 786-8678 Fax: 1 (818) 765-0031 Website: www.uu77.com Email mcgillsales@mcgillsglass.com A group of manufacturers and importers share this site. Look here first to find out what the right price is for products even if you buy locally.

Ward Burner Systems

See in online information section

Regulators

Jay Hayes

Email: xmas4lites@earthlink.net
Excellent quality and low priced LPG regulator Fisher model #67/743 for use with small gas forges. These regulators are industrial rated and UL approved for use with LP gas. They are adjustable to 35 PSIG and provide 700,000 Btu.

Rego products

They are a manufacturer and distributor of quality equipment for LPG including needle valves and pressure regulators.
Website: http://www.ecii.com/

Screwfix Direct Ltd.

Houndstone Business Park Yeovil BA22 8RT. Registered in England # 3006378 Website: www.screwfix.com Regulator: 0-4 Bar with pigtail and low priced.

Rigidizers

Fiberfrax Rigidizer

Rigidizer W available from Unifrax Corp. 2351 Whirlpool St., Niagara Falls, N Y 14305-2413 Tel: 1 (716) 278-3800 Fax: 1 (716) 728-3904 Some of these products are available from some of the other sources listed.

Unifrax Corporation

Canada P.O. Box 1006 Niagara Falls, Ontario L2E 6V9 Tel: 1 (800) 635-4464 Fax: 1(716) 278-3904 Website: http://www.unifrax.com/ This is Coloidal silica.

Zircar Refractory Composites, Inc.

P.O. BOX 489 Florida, New York 10921 Tel: 1 (845) 651-2200, Fax: 1 (845) 651-1515

This is Alumina rigidizer (Zircar Alumina Coat).
Website:http://208.228.96.228/alumcoat.htm Email: sales@zrci.com 1-800-361-4652, in Mississauga, Canada.

Sairset

Air Heat Supplies

1-800-361-4652, in Mississauga, Canada.Seattle Pottery Supply

Clay Art Center

See under Refractory and Insulation Materials.

Seattle Pottery Supply

See under Online Information.

Tucker's Pottery Supplies Inc.

15 West Pearce St., Richmond Hill, Ontario, Canada L4B 1H6 Tel: 1 (800) 304-6185
1 (905) 889-7705 Fax: 1 (905) 889-7701
Website: http://www.tuckerspottery.com/index.html Email: tuckers@passport.ca

Welding Supplies

See your local dealers for MIG tips, leathers, welding hoods, safety glasses, gloves, welding supplies, grinding and sanding disks. Drop by a welding shop and ask them what they would recommend.

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New Burner Applications

The following photographs and information are the result of metalworkers using their own ideas as they have been developed and expanded from this book. Both Michael Porter and I hope that you will show the same inventiveness and challenge. *The publisher*

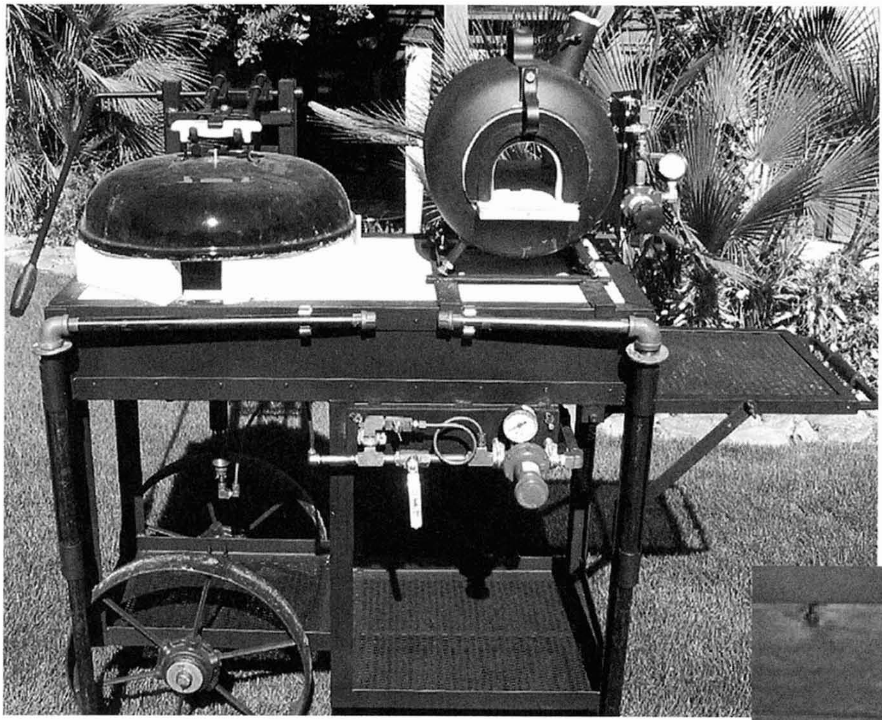


Fig. 13-1 A front view of Doug Endrud's complete forge heating system, comprising a tube forge mounted over the insulated table-top's right end and a clamshell fixture on the left side. It has swing arms to hold stock, large wheels for the outdoors, and a swing up extension table.

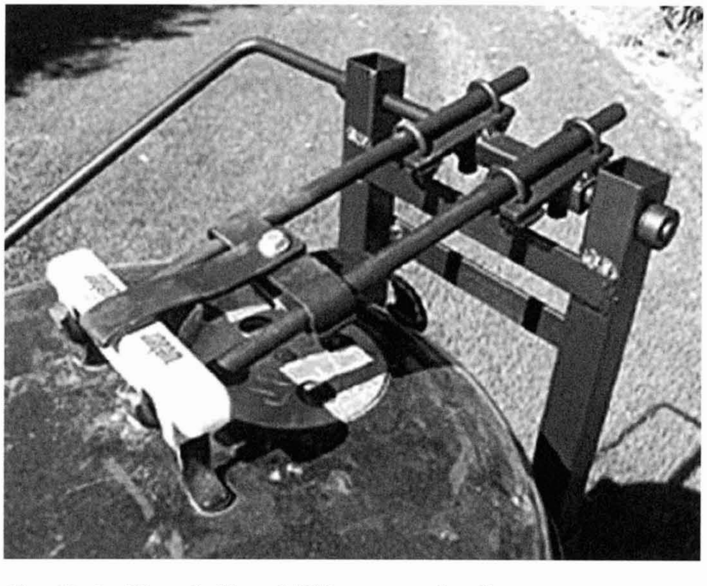


Fig. 13-2 Clamshell and lifting arm details.

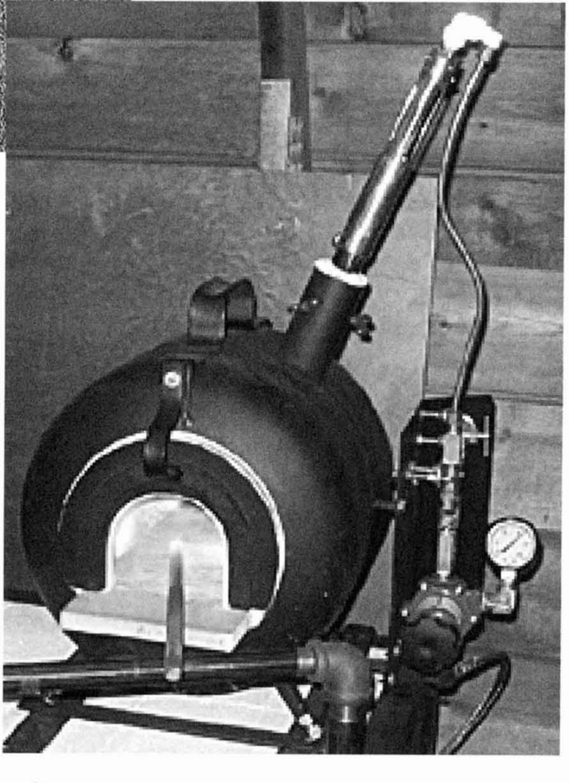


Fig. 13-3 Swing arm and tube forge in action.

Alfredo Allamo's forge cart and heating system has piezoelectric ignition and hi/low switches for all three burners.

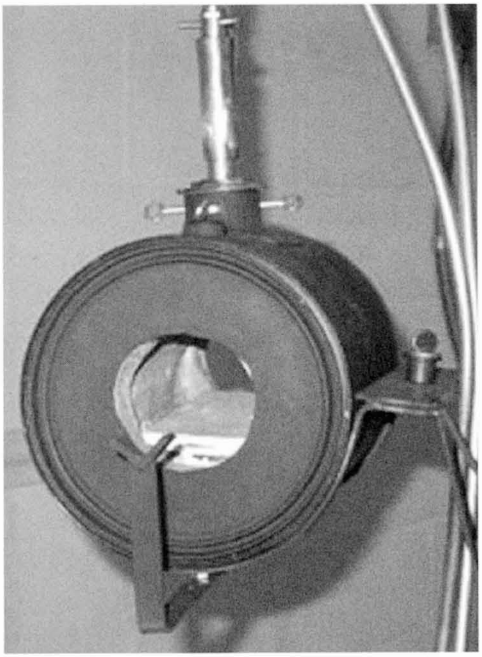


Fig. 13-4 Paint can forge and 1/2" burner.

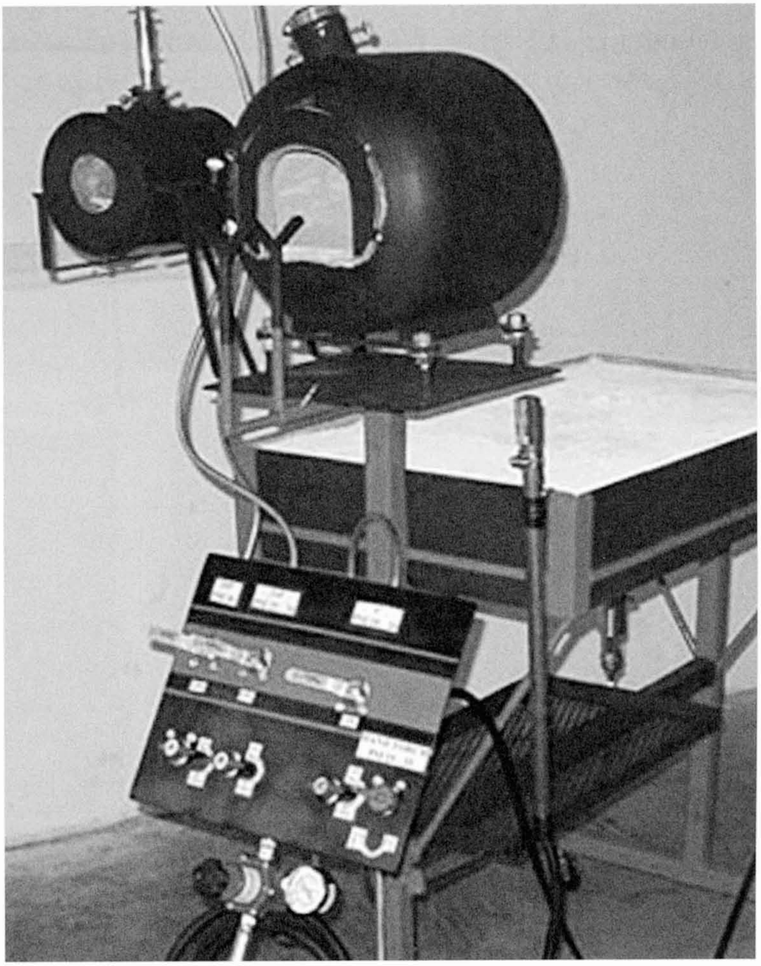


Fig. 13-5 Propane bottle forge with 1/2" burner.

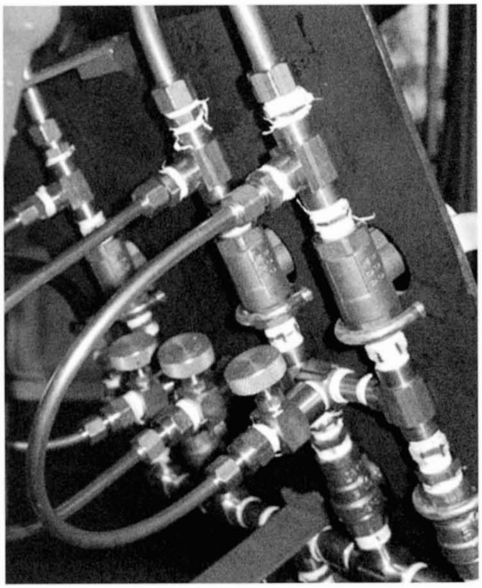


Fig. 13-6 Back of panel: Manifold with needle valves.

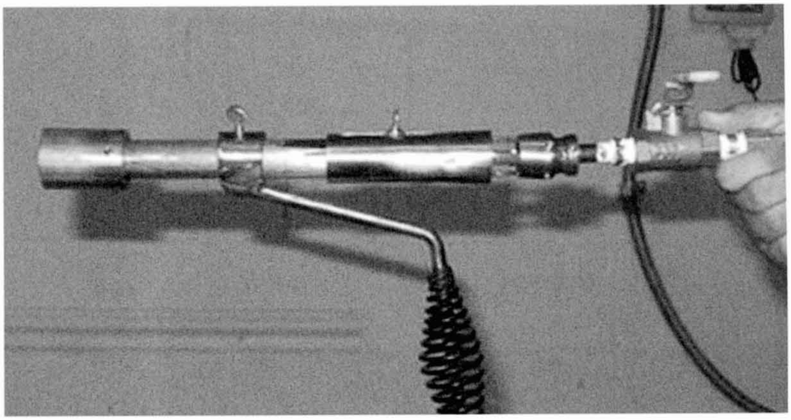
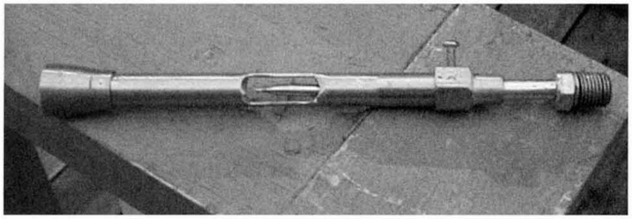
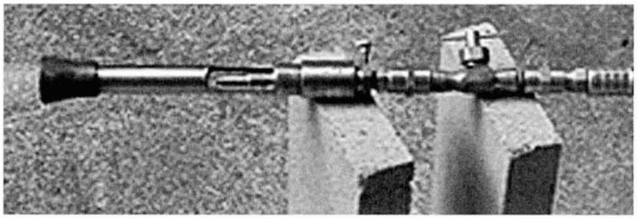


Fig. 13-7 3/4-inch burner on fuel hose with a removable handle.

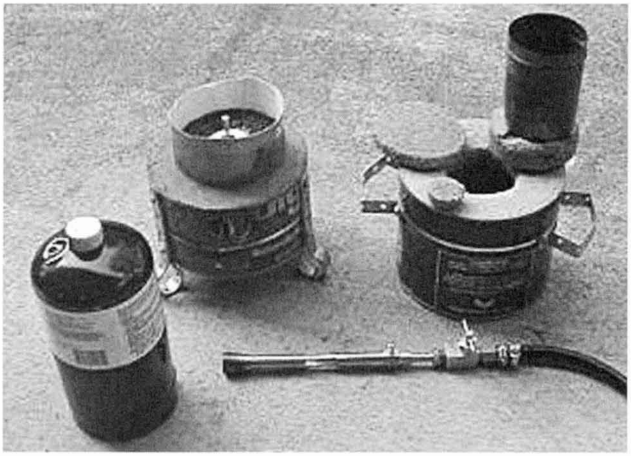
Gene Elliott, in Gig Harbor, WA, has built a number of burners and furnaces using this book. Along with the coffee can furnace he is constructing Multi-hole and miniature Multi-hole furnaces.



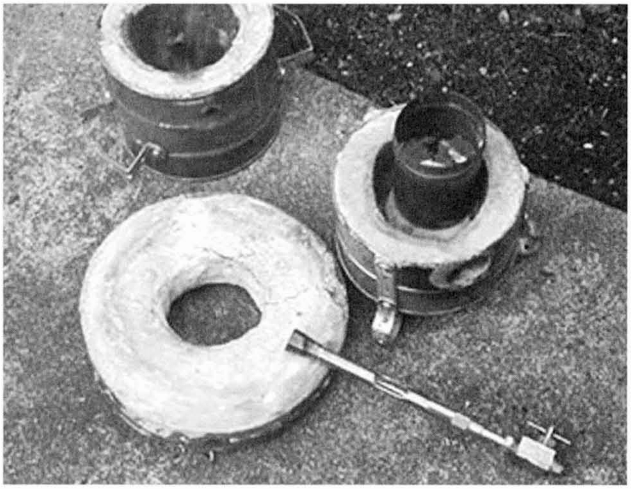
Fig, 13-8 Gene's 1/4-inch burner design.



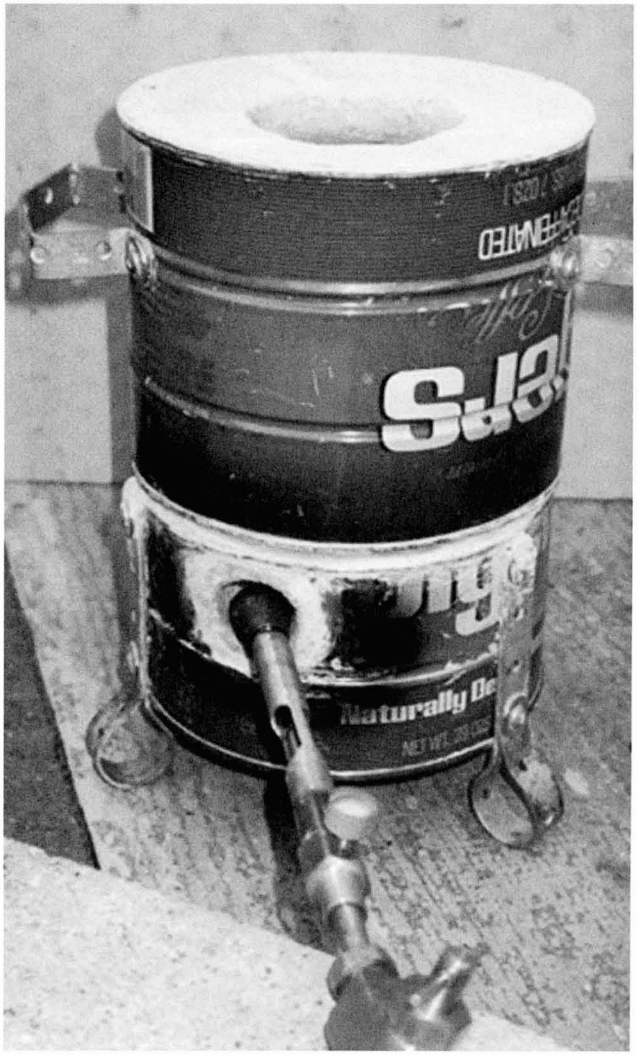
Fig, 13-9 3/8-inch burner



Fig, 13-10 Furnace and accessories (under construction)

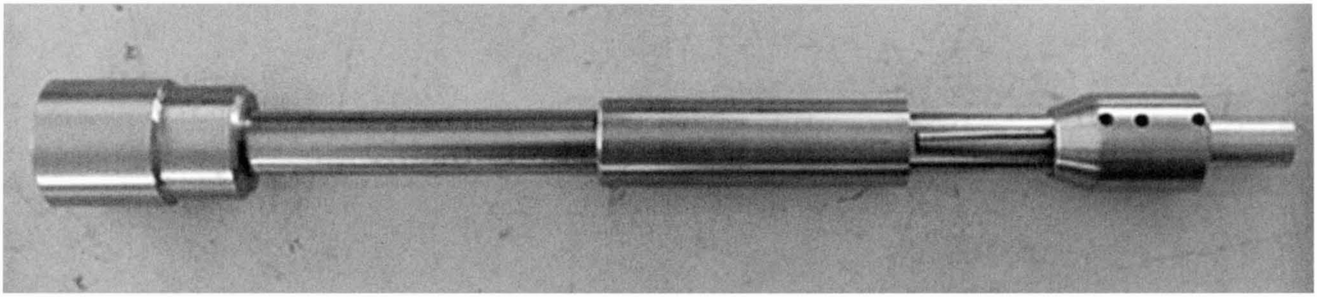


Fig, 13-11 Large furnace lid and burner for Coffee Can furnace.

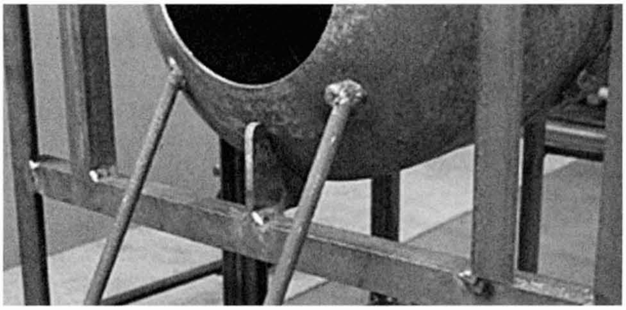


Fig, 13-12 Furnace and burner in position.

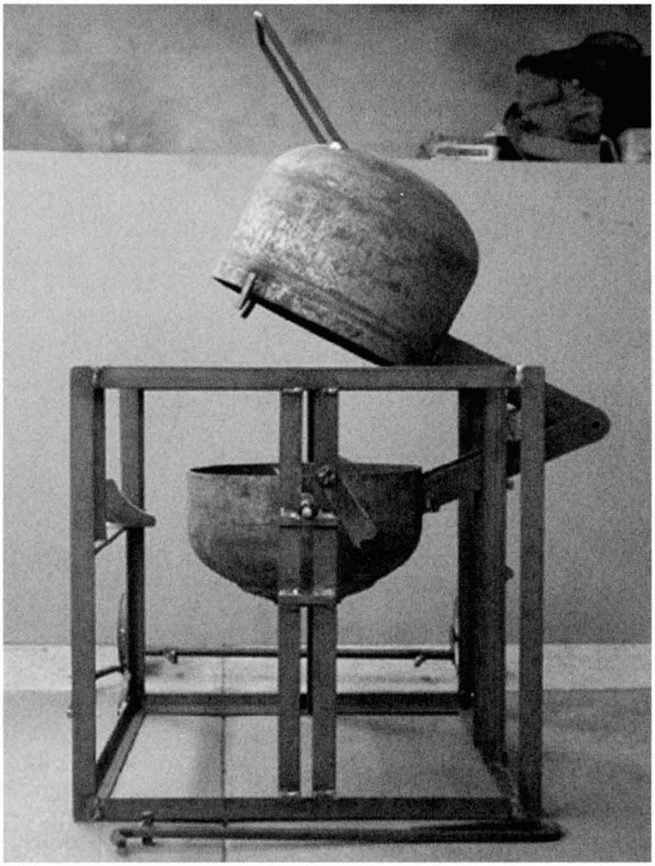
Frank Hasiber's 1/2-inch burner and Multi-hole furnace.



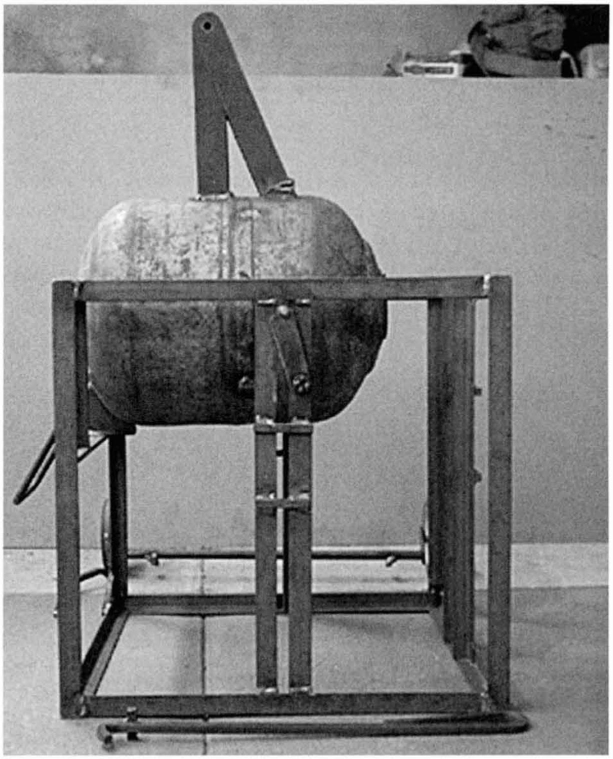
Fig, 13-13 This burner is easily capable of heating the Multi-hole.



Fig, 13-14 Front support and locking stop.

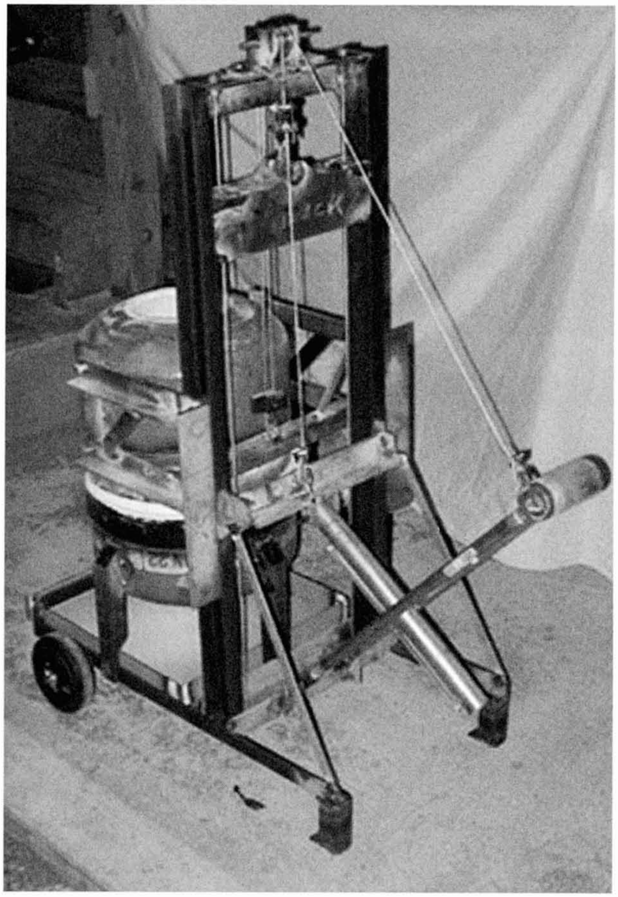


Fig, 13-15 Lowered position open to show hinge change.

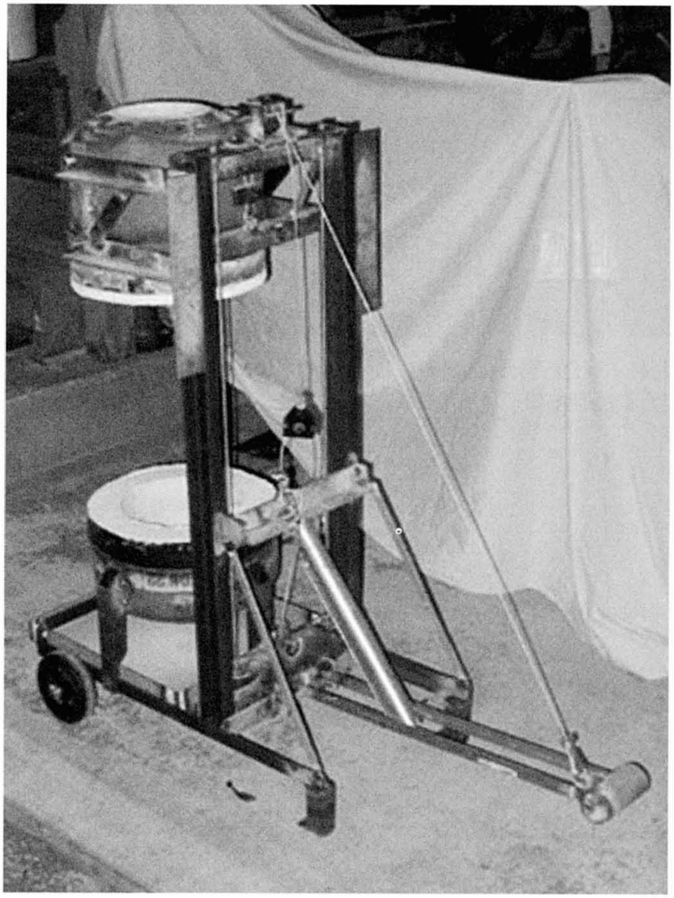


Fig, 13-16 Raised and locked in horizontal position.

Reed Streifthau's Top Hat portable furnace.



Fig, 13-17 Cabled lift

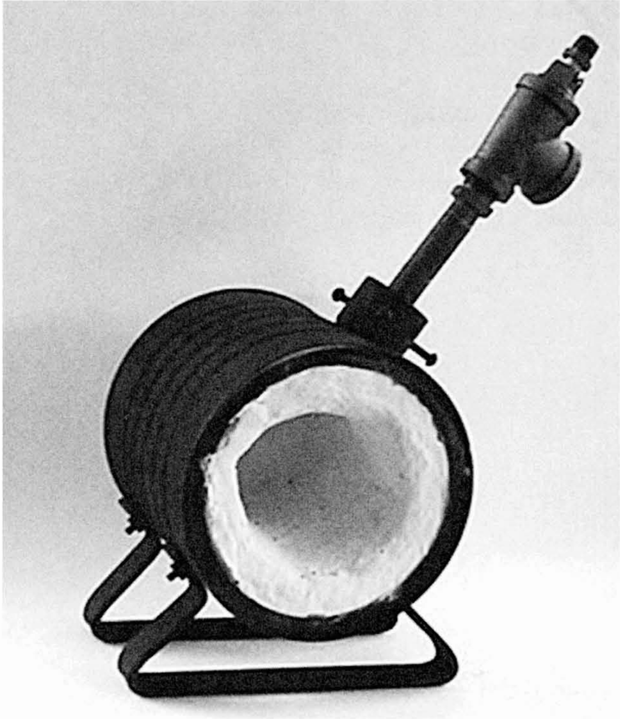


Fig, 13-18 Furnace top raised by lift.

BES Ltd. Mail Order Gas & Plumbing Supplies (excellent English source)

http://www.bes.ltd.uk/nav_graf/frames_cat.htm Tel: 0800 80 10 90 They offer quality valves, regulators, fittings, hoses, and even LPG torches at low prices, shipping around the world (for free with larger orders). Look in "LPG & Oil" section.

Larry Zoellers Coffee Can Forge, Micro Burner, and new parts lists (see also Resources listing).



Fig, 13-19

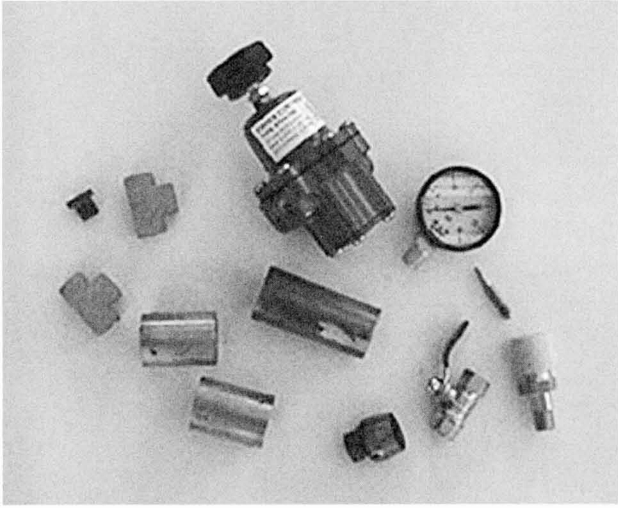
1/2" Tube Burner Parts Price List

(1A, 1B) S S Burner Nozzle	$12.00
(2) Burner Tube	$28.00
(3, 5) Advanced Choke Sleeve	$8.00
(4) Advanced Bell Reducer	$8.00
(6) Advanced Accelerator	$6.00
(7) .023 Mig Contact Tip	$3.00
Total	$65.00

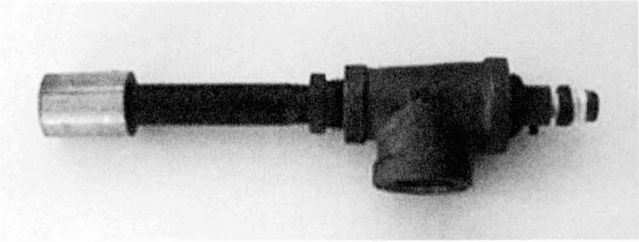
3/4" Tube Burner Parts Price List

(1A, 1B) S S Burner Nozzle	$15.00
(2) Burner Tube	$30.00
(3, 5) Advanced Choke Sleeve	$8.00
(4) Advanced Bell Reducer	$10.00
(6) Advanced Accelerator	$6.00
(7) .035 Mig Contact Tip	$3.00
Total	$72.00

The numbers on the parts list above represent corresponding parts numbers in the materials lists of this book. Each piece can be purchased separately or sold as part of a kit. S&H is not included in the price list. Please contact Larry with a list of parts wanted, and he will send you a shipping quote by E-mail or phone. If you have any questions feel free to contact him at zman59@earthlink.net or phone 1-502-367-0706.



Fig, 13-20



Fig, 13-21

Ordering Information for SkipJack Books

Orders for SkipJack books are processed Bookmasters, a fulfillment service. Books are available 24/7 and are shipped by UPS. Overseas shipping is handled on an individual basis. For quantity orders call for discount information. Below is the current list of Skipjack books.

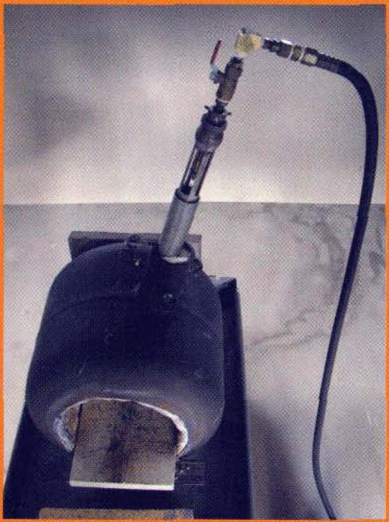
Contact Bookmasters by:
1-800-247-6553 fx 1-419-281-6883
www.skipjackpress.com/

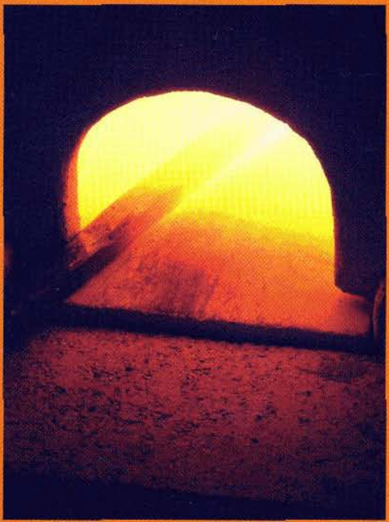
Gas Burners for Forges, Furnaces, and Kilns, Porter Paper back, 224 pages, 2004	$19.95
New Edge of the Anvil, Andrews Paper back, 256 pages, 2002	$25.00
Golden Age of Ironwork, Magaziner Hard cover, 224 pages, 2000	$34.00
Samuel Yellin, Metalworker, Andrews Paper back, 144 pages, 2000	$19.95
Colonial Wrought Iron, Plummer Hard cover, 256 pages, 1999	$39.00

SkipJack Press
6 Laport Court
Ocean Pines, MD 21811

skipjack394@mchsi.com

SkipJack Press





About the author

Mike Porter began learning ornamental ironwork at twelve in his father's shop during the fifeties building boom. Low profit margin and high demand combined to make Southern California a center for technical innovation in trade work. First rate tooling was simply a matter of survival. Over the years his passions for exceptional tooling and for the crafts merged into a unified veiw of art; that vision and tooling are inseperable, for one will not outpace the other. His book is meant to help address the disparity between desire and ability that is holding up progress in the crafts today.

About the book

Explains how to make:

- Gas burners for a forge
- Hand torch for metal arts
- Crucible furnace for metal and more!

All equipment constructed from readily available materials

Full instructions and illustrations

Appropriate for beginners

The burners are gas jet ejectors and are naturally aspirated

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